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A CRITICAL REVIEW OF THE WORLD LITERATURE IN APPLIED MECHANICS AND RELATED ENGINEERING SCIENCE

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APPLIED MECHANICS REVIEWS

VOL. 7, NO. 10 MARTIN GOLAND *Editor* OCTOBER 1954

LIMIT ANALYSIS AND DESIGN

D. C. DRUCKER

BROWN UNIVERSITY, PROVIDENCE, R. I.

INTRODUCTION

ALTHOUGH plastic design procedures are now becoming quite respectable in the engineering profession, it is probably worth repeating the reasons for the present trend toward consideration of plasticity. Certainly most machine or structural elements and assemblies are designed so that nominal working stresses are well within the elastic range of structural metals. Measured working deflections and strains will therefore check well in most cases with those computed by an elastic theory which is sufficiently inclusive. Nevertheless, any type of elastic design or analysis, whether of the simplest or of the most elaborate type, is often irrelevant. A given part or structure is expected to withstand overload successfully and should not fail until a sizable multiple of the working load is applied. At this overload, which is the highest that can be designed for economically, the failure which occurs may be a fracture of the brittle, fatigue, or ductile type. It may instead be a matter of excessive deflection or deformation. In the majority of cases, the loads are not of the fatigue type and the metal is ductile in the presence of notches at the temperature of use. Large plastic action then takes place prior to failure and the stress distribution generally changes radically from the elastic pattern. A plastic analysis is therefore essential for an understanding of what happens and for achievement of the best design. Plasticity rather than elasticity is also obviously needed in the study of metal forming and allied processes.

Limit analysis and design have the rather narrow objective of determining the load-carrying capacity (called the limit or collapse load) of a given design or, conversely, of determining the design for strength under a given system of loads. It is part of a very special branch of the theory of plasticity in which a flat yield or ideally plastic material is assumed [AMR **4,** Rev. 4444]. If the yield stress is taken as the yield point of the material, all work hardening is ignored. The work hardening may be averaged in a crude but reasonably effective manner by taking an effective yield stress higher than the yield point.

The main feature of limit analysis, as the term will be employed here, is that a complete solution is avoided. This is, of course, a great advantage. On the debit side there is the omission of the problems of buckling, progressive failure and fracture. Also, although the limit load approximates the load at which the deformation of an actual body starts to increase rapidly, deflection calculations are not a part of limit analysis. To obtain a clearer picture of the meaning of limit analysis, consider a continuous beam of nonuniform cross section loaded uniformly over half of one span. Limit analysis answers a question such as: (a) Is the beam strong enough to carry the load? or (b) What is the maximum intensity of load the beam can carry? or (c) What concentrated force can be added at midspan before the beam collapses? Each question is answered without going through the tedious step-by-step process of increasing the load from zero, finding the elastic solution, determining which section of the beam goes plastic first and forms a yield hinge, obtaining a new elastic solution with a constant hinge moment equal to the limit moment, and so on until the beam or perhaps the computer collapses. In two dimensions, for example, Drucker, Greenberg, Lee, and Prager [AMR **6,** Rev. 2718] could show simply that a thick-walled square tube of the side dimension D and central hole diameter d has exactly the same interior limit pressure as a circular tube of outside diameter D and inside diameter d. The elastic-plastic solution for the thick-walled square tube was irrelevant and was not even studied. In constrast to analysis, limit design provides the answer to the problem of finding the beam of minimum weight to carry the given loading. Exact elastic or plastic solutions are difficult beyond practical means in all but a few of the simple and fundamental cases. Limit analysis and design can be achieved with moderate effort, on the other hand, even in quite complicated examples. Furthermore, almost exact answers for the limit or collapse loading are generally not worth the large but relatively moderate effort. Reasonably close upper and lower bounds to the limit load which can often be found quickly are sufficient for practical use.

BRIEF HISTORY

Much of the early work by the pioneers in the field, Kazinesy, Kist, Johansen, Maier-Leibnitz, van den Broek, Baker, Johnston, and others, was based upon an intuitive feeling about the behavior of structures. This feeling was fortified by a number of detailed plastic analyses and considerable engineering experience. Although many of the results obtained were very useful, it was not always clear how the techniques could be extended to other problems. The limit theorems for plane frames had themselves a somewhat ambiguous status until proved by Greenberg and Prager in 1949 [AMR **5,** Rev. 1696].

The fundamental theorems and concepts of limit analysis in practical form for three-dimensional bodies are very recent indeed. They appeared first in Brown University reports by Drucker, Greenberg, and Prager [AMR **5,** Revs. 432, 1695] to the

Office of Naval Research in 1950, and in 1951 [AMR **4,** Rev. 4444]. The unfortunate effects of publication delay in the United States on the necessary cooperation, interaction, and competition among research workers was minimized by widespread distribution of the reports in the United States and abroad. Many advances in analysis were stimulated mutually in this way. Special mention should be made of the work by R. Hill [AMR **5,** Rev. 693; **6,** Rev. 3739] and his associates in England. Their work, which does appear quickly in print, has been built upon further by groups in this country and elsewhere with a consequent rapid acceleration in the development of the subject. Specialization and application of the theorems to plates by Pell and Prager [AMR **6,** Rev. 3033], Hopkins and Prager [AMR **7,** 1752], Drucker and Hopkins [2nd U. S. National Congress of Applied Mechanics, in press] are more recent, and application to shells by Drucker [1st Midwestern Conf. Solid Mech., Engng. Exp. Sta., Univ. of Ill., 158–163, Apr. 1953] and by Onat and Prager is more recent still.

Most attention has been paid to civil-engineering structures. Problems in this group which have been solved range from the first step analysis of a simply supported beam through the continuous beam, simple and elaborate frames excluding and later including the effects of axial force, arches, grids, and space frames in which torsion is combined with bending, flat slabs (rectangular plates), perforated tension members, and footings (punches). Limit analysis of plane frames has been carried to a high degree of perfection by Neal and Symonds [AMR **5,** Rev. 2598; **6,** Rev. 1217] with a technique of combining mechanisms of failure. The design problem is, of course, a much more difficult one, but a great deal is known about both design and analysis from their studies [AMR **5,** Rev. 2361] and from the work of Heyman [AMR **5,** Rev. 92; **4,** Rev. 2889; **7,** Rev. 768], Hrennikoff [AMR **1,** Rev. 55], Horne [AMR **3,** Rev. 1928; **4,** Rev. 3864], Craemer [AMR **5,** Rev. 3078], Roderick [AMR **1,** Rev. 1632], Phillips [AMR **3,** Rev. 1948], and Foulkes [AMR **6,** Rev. 2787]. Invaluable and extensive experimental information about frames combined with methods of calculation has been gathered and is accumulating rapidly under the direction of Baker at Cambridge [AMR **3,** Rev. 2632; **5,** Rev. 2597] and Johnston and Beedle in the Lehigh Laboratories [AMR **6,** Rev. 1874]. Surveys of the field have been given by Baker [AMR **5,** Rev. 668], by Symonds [AMR **4,** Rev. 3204; **5,** Rev. 2016], and by Johnston, Yang, and Beedle [AMR **7,** Rev. 1797].

By comparison, relatively little is known about the two-dimensional problem and much less about how to solve a three-dimensional one of the complicated type found in practice. Some limit solutions as distinguished from plastic analyses have been to the problems of notched bars in bending by Green [AMR **7,** Rev. 103], reinforcement of plate openings by Weiss, Prager, Hodge [AMR **6,** Rev. 803], rectangular footings by Shield and Drucker [AMR **7,** Rev. 1105], and experimental corroboration found by Watts and Ford [AMR **7,** Rev. 492] for a surprising solution by Green [AMR **5,** Rev. 114] on material between rigid plates, and by Brady and Drucker [AMR **7,** Rev. 1474] for sheets under tension with various configurations of holes. As Drucker, Greenberg, Lee, and Prager [AMR **6,** Rev. 2718] point out, the so-called complete solutions for plastic-rigid bodies give correct limit loads for an elastic-plastic body, velocity solutions give upper bounds, and stress solutions give lower bounds.

Application of limit analysis to soil mechanics by Drucker and Prager [AMR **6,** Rev. 299; **7,** Rev. 2004] leads to some interesting and important results on stability of slopes, especially when the inability of soil to take appreciable tension is included by postulating inability to take any tension. The analysis by Kooharian [AMR **6,** Rev. 2760] of the Voussoir arch as a structure able to take practically unlimited compression and no tension is another allied application of the limit theorems.

LIMIT ANALYSIS THEOREMS

The basic concepts of limit analysis and design are remarkably simple. For an elastic ideally plastic material:

1 Neglecting changes in geometry (as in most elasticity problems), stresses remain constant as plastic collapse takes place and collapse occurs under constant load, termed the collapse or limit load.

2 Collapse will not occur if any state or stress can be found which is below yield at every point and which satisfies the equations of equilibrium and the boundary conditions on stress. This theorem gives lower bounds on the limit loading.

3 Collapse must occur if, for any compatible flow pattern, considered as plastic only, the rate at which the external forces do work equals or exceeds the rate of internal dissipation. This theorem gives upper bounds on the limit loading.

In less precise language the theorems state that the body will withstand the applied loads by rearranging the internal stresses to best advantage. On the other hand, if a means of collapse exists, the body gives up.

Some corollaries of the theorems are:

4 Addition of (weightless) material cannot result in a lower collapse load.

5 Increasing the yield strength of the material in any region of an ideally plastic body cannot weaken the body.

6 Initial stresses or deformations have no effect on the collapse or limit loads, provided the geometry is essentially unaltered.

The negative form of corollaries 4 and 5 are awkward but required. It is not necessarily true, for example, that addition of material or increase in yield stress will produce an increase in strength. They may, but the strongest statement that can be made is that the altered body is not weaker.

YIELD CONDITIONS

The terms appearing in the theorems are directly interpretable for three-dimensional states of stress. The yield condition may be any one relevant to the material and the problem at hand. The maximum shearing stress criterion and the shear strain energy criterion are chosen most often, but any other isotropic or anisotropic form, symmetrical or otherwise with respect to tension and compression, is permissible. When structural elements are analyzed, the "stress" components are generally stress resultants instead. In a beam, for example, the simplest theory takes bending alone into account and moment plays the role of stress. The slightly more elaborate theory developed for building frames and for arches includes axial force, and a more elaborate one still considers shear force in addition to moment or in addition to moment and axial force. In a plate or a shell, moment components alone may be considered or moments may be combined with membrane forces. The inclusion of transverse shear is the next step. The main point to keep in mind is that the degree of complexity and the quantities chosen are arbitrary to a considerable extent and should be controlled by the range of the significant variables of the problem.

Strain rates are to be interpreted in a broad sense also. If, for example, the stress quantity is moment, the strain rate associated with it is rate of curvature; if torque, then rate of twist, etc.

There is a strong tie between the yield surface and the extended concept of a plastic potential which includes surfaces with corners. It is no accident that the limit theorems are all valid when the yield function and the generalized plastic potential coincide and

not otherwise. The thermodynamic reasoning is similar to that used by Drucker [AMR **6**, Rev. 2513] to establish the convexity of the yield surface The postulate is that in a closed cycle work cannot be extracted from the body and the system of forces acting upon it. It follows then that the strain rates associated with the purely plastic flow which takes place during collapse are normal to the yield surface at a smooth point and lie on or between adjacent normals at a corner.

A further restriction is that the yield function must correspond to a stable or a neutrally stable material in order for all the theorems to apply. Mild steel with its upper yield point and drop to lower yield point is really not a stable material. Fortunately, ignoring the upper yield point leads to a safe and an entirely reasonable result.

DIFFICULTIES AND LIMITATIONS

The difficulty appearing in two- and three-dimensional problems is that the number of permissible independent kinematic solutions, each of which determines an upper bound, is multiply infinite instead of finite, as for frames under concentrated loads. A good solution, to say nothing of the best one, is often hard to spot. The same trouble appears in the lower bound equilibrium solutions, often in aggravated form. A very clever use of curved discontinuities in a two-dimensional stress field by Bishop [AMR **7**, Rev. 1793], in addition to the straight discontinuities of Prager [AMR **2**, Rev. 186] which have proved so helpful in the past, offers great promise for improvement of lower bounds and may well break the bottleneck in the flow of solutions to problems of practical value. Shield has applied the technique to soil-mechanics problems and it can be extended to three dimensions.

The limitations of limit analysis are of considerable importance. Structures containing slender members whose primary function is to carry compression are generally not amenable to limit analysis, but require a study of instability in the plastic range instead [AMR **6**, Rev. 3397]. Basically the reason is that the load on a member which buckles plastically, whether column, plate, or shell, usually decreases sharply as a deflection increases past the maximum load point. Elastic buckling of columns, on the contrary, takes place under essentially constant load. The limit theorems for elastic trusses have been studied by Masur [AMR **7**, Rev. 464].

The neglect or averaging of strain hardening involves a different type of limitation. A limit load in practice does not produce a horizontal line on a load-deflection plot. It is only in exceptional problems, however, that strain hardening has a completely obliterating effect on the limit loading provided proper measures of deformation are employed. In a tension plate with a single transverse row of holes, for example, if load is plotted against over-all elongation, the limit load is indeed obscured. If load is plotted against local deformation as measured by a short strain gage at the net section or by a thickness gage there, the limit load is clearly and sharply defined.

A large number of examples do exist where the limit load is not apparent from any experimental data without special computation. Experiments on plates under transverse load demonstrate that limit analysis does not always supply the answer to a practical problem. This is not surprising for very thin plates such as those tested by Cooper and Shifrin, which act primarily as membranes; but the effect is still quite strong in the relatively far thicker plates tested by Haythornthwaite and by Foulkes and Onat as described during the recent 2nd U. S. National Congress of Applied Mechanics.

The real limitation of the limit procedure lies in the fundamental postulate "neglecting changes in geometry." This requires that both elastic and plastic deformations introduce no large secondary stresses and is not a limit on the absolute magnitude of deflection. A beam can deflect appreciably in the elastic range without affecting the significance of the limit load. A plate of the same span will have large membrane stresses induced for a far smaller deflection, and the limit load may have much less physical meaning.

There has been some tendency recently to speak of rigid-plastic material rather than elastic-plastic so that the limit load is the yield point and has exact mathematical meaning. First flow and collapse are then coincident and the geometry up to the point of collapse is strictly unaltered. This subterfuge is not truly helpful in physical problems [Lee, AMR **5**, Rev. 96] and, furthermore, does not actually avoid the necessity of considering the secondary stresses which may be due to plastic as well as to elastic deformation.

FRICTIONAL INTERFACES

The limit theorems do not always apply directly to assemblages of bodies with frictional interfaces. They do apply if the coefficient of friction is zero or, obviously, also if there is no relative motion at the interfaces. No relative motion is a more restrictive term than infinite friction because separation is not permitted. When there is finite friction, it is advantageous to include the concept of an interface cement composed of a cohesionless soil with an angle of friction. The soil is postulated to obey the laws of plasticity. The usual limit theorems then apply to the assemblage of bodies cemented together in this way. With this background the following theorems were established by Drucker [AMR **7**, Rev. 1788]:

7 Any set of loads which produces collapse for the condition of no relative motion at the interfaces will produce collapse for finite friction.

8 Any set of loads which will not cause collapse when all coefficients of friction are zero will not produce collapse with any value of the coefficients.

9 Any set of load which will not cause collapse of an assemblage of bodies with frictional interfaces will not produce collapse when the interfaces are "cemented" together with a cohesionless "soil" of the same friction angle.

In these theorems, as in the previous corollaries 4 and 5, the inverted type of wording is necessary. Reworded, the theorems state that the limit load for an assemblage of bodies with frictional interfaces is bounded below by the limit load for the same bodies with zero friction on the interfaces. It is bounded above by the limit load for no relative motion at the interfaces and also by the limit load for the same assemblage cemented at the interfaces with a cohesionless soil. Limit theorems applicable to these bounding problems do not apply generally.

A conclusion which can be drawn immediately from the theorems is that the limit load for a two-dimensional flat rigid punch on a semi-infinite Prandtl-Reuss or von Mises solid is independent of the coefficient of friction on the surface of contact. The result follows directly from the equality of the limit loads for a perfectly smooth and for a perfectly adhering punch.

Books Received for Review

British Iron and Steel Research Association, edited by, Physical constants of some commercial steels at elevated temperatures, London, Butterworths Scientific Publications, Ltd., 1953, x + 38 pp. $3.50.

Daugherty, R. L., and Ingersoll, A. C., Fluid mechanics with engineering applications, new 5th ed., New York, Toronto, London, McGraw-Hill Book Co., Inc., 1954, xiii + 472 pp. $7.

DOLAND, J. J., Hydro power engineering, New York, The Ronald Press Co., 1954, vi + 209 pp. $7.50.

HOFF, H., AND DAHL, T., Walzen und Kalibrieren, Düsseldorf, Verlag Stahleisen M. B. H., 1954, xi + 216 pp., 202 figs., 63 tables. DM 22.50.

KAUFMANN, W., Technische Hydro- und Aeromechanik, Berlin, Springer-Verlag, 1954, viii + 352 pp., 254 figs. DM 36.

KING, H. W., Handbook of hydraulics, 4th ed. (revised by Brater, E. F.), New York, Toronto, London, McGraw-Hill Book Co., Inc., 1954, xvii + 463 pp. $8.

KUMANIN, I. B., AND LJASS, A. M., Kernbinderwerkstoffe, Berlin, Verlag Technik, 1953, 256 pp., 52 figs., 6 tables. DM 28.

MADELUNG, E., Die Mathematischen hilfsmittel des Physikers, 5th ed. (Die Grundlehren der Mathematischen Wissenschaften, Bd. IV), Berlin, Springer-Verlag, 1953, xx + 531 pp., 29 figs. DM 49.70.

NÖRLUND, N. E., Differenzenrechnung, New York, Chelsea Publishing Co., 1954, ix + 551 pp., 34 figs.

OSGOOD, W. R., edited by, Residual stresses in metals and metal construction, New York, Reinhold Publishing Corp., 1954, xii + 363 pp. $10.

POPE, A., Wind tunnel testing, 2nd ed., New York, John Wiley & Sons, Inc.; London, Chapman & Hall, Ltd., 1954, xv + 511 pp. $8.50.

PÖSCHL, H., Verbindungselemente der Feinwerktechnik (Konstruktionsbücher, Bd. 14), Berlin, Springer-Verlag, 1954, v + 108 pp., 741 figs. DM 13.50.

RAUSIN, J. R., Warmbehandlung von Chromstahl, Berlin, Verlag Technik, 1952, 174 pp., 190 figs. DM 20.

ROTHE, A., Stabstatik. Grundlagen und Verfahren der Statik ebener Rahmentragwerke, Berlin, Verlag Technik, 1953, 155 pp., 14 figs., 3 tables. DM 24.

SAUER, R., Anfangswertprobleme bei partiellen Differentialgleichungen (Die Grundlehren der mathematischen Wissenschaften, Bd. XLII), Berlin, Springer-Verlag, 1952, xiv + 229 pp., 63 figs. DM 29.

SCHIEBEL, A., Zahnräder. Bd. I. Stirn- und Kegelräder mit geraden Zähnen, 4th rev. ed. (revised by Lindner, W.), Berlin, Springer-Verlag, 1954, vi + 133 pp., 183 figs. DM 18.

SOROKIN, L. W., URYSSON, W. O., RYABINKIN, L. A., AND DOLIZKIJ, W. A., Lehrbuch der geophysikalischen Methoden zür Erkundung von Erdolvorkommen, Berlin, Verlag Technik, 1953, 578 pp., 231 figs. DM 34.

ZWIKKER, C., Physical properties of solid materials, New York, Interscience Publishers, 1954, viii + 300 pp. $8.75.

Letters to the Editor

3083. Re AMR 7, Rev. 2595 (August 1954): F. W. Sinden, On the thermodynamics of irreversible processes.

Title should read: "An oscillation theorem for algebraic eigenvalue problems."

The editors regret this error.

3084. Re AMR 7, Rev. 1306 (April 1954): L. Ting, Diffraction and reflection of weak shocks by structures.

The reviewer should have stated that solution for thin barrier is given during nth time interval in terms of the $(n - 1)$ solutions for the preceding time interval, where a time interval corresponds to plane wave propagation through one barrier height, explicit solutions being given for the first three such intervals.

J. Miles, USA

3085. Re AMR 7, Rev. 1682 (May 1954): A. A. Raimondi and J. Boyd, Applying bearing theory to the analysis and design of pad-type bearings, Parts I and II.

Some clarification of my review is evidently desirable. I do not wish to imply that the authors of this article had overlooked or had not thoroughly discussed (which they have) the subject of viscosity. I merely wished to point out a limitation of the method which becomes more than inconsequential for certain types of pivoted pad bearings. W. Anderson, USA

Theoretical and Experimental Methods

(See also Revs. 3114, 3131, 3166, 3189, 3265, 3280, 3294, 3300, 3345, 3346, 3436)

3086. Ver Planck, D. W., and Teare, B. R., Jr., Engineering analysis, an introduction to professional method, New York, John Wiley and Sons, Inc.; London, Chapman & Hall, Ltd., 1954, xii + 344 pp. $6.

Most important features are the philosophy of approaching problems logically and systematically, the application of fundamental principles, and exercise of engineering judgment. Emphasis is on the whole thinking process of translating engineering situations into mathematical language, interpreting and understanding the mathematical result, and presenting the answer in a form most suitable for future use. More specifically, the book deals with such matters as: defining the problem to be solved; deciding what principles to apply; choosing coordinate systems; checking thoroughly; choosing dimensionless variables; and the sketching of curves. Adequately endowed with examples from all branches of engineering, including dynamics, electricity, magnetism, heat transfer, solution of differential equations, use of power series, graphical and numerical integration, hyperbolic functions, and the evaluation of indeterminate forms, the book treats the topics from the point of view of use and true understanding. A. Whillier, USA

3087. Muskhelishvili, N. I., Singular integral equations, 2nd ed. (translated from Russian by Radok, J. R. M.), Groningen, Holland, P. Noordhoff, Ltd., 1953, 447 pp. Fl. 28.50.

For comprehension of this book the theory of functions of a complex variable and the theory of Fredholm integral equations are necessary.

The first part of the book deals with one-dimensional singular equations involving Cauchy principal values. Important formulas due to Plemelj, Poincaré-Bertrand, and Hilbert are proved. Also included in the first part are results due mainly to the author on the behavior of Cauchy integrals near the ends of the path of integration.

In the second part, author shows the connection between the Hilbert and Riemann-Hilbert boundary-value problems and singular integral equations having Cauchy-type kernels.

The Dirichlet problem, a special case of the Riemann-Hilbert problem, representations of holomorphic functions, and the generalization of the Riemann-Hilbert-Poincaré problem constitute the subject matter of the third part of the treatise.

In the fourth part, certain fundamental formulas of the plane theory of elasticity are derived and applied to such problems as these, namely, the pressure of rigid stamps on the boundary of an elastic half-plane in the absence as well as in the presence of friction and of contact of two elastic bodies.

Part five is devoted to the theory of singular equations involving Cauchy integrals in which the path of integration is the union of smooth arcs and the coefficients are either continuous or discontinuous functions. The theory is then applied to the solution of an integrodifferential equation arising in the theory of aircraft wings of finite span.

Finally, in part six, systems of singular equations are considered.

Those interested in potential theory, the theory of elasticity, the theory of fluid mechanics, or mathematical physics in general, will find the perusal of this treatise rewarding.

E. J. Scott, USA

3088. **Wagner, C., On the numerical solution of Volterra integral equations,** *J. Math. Phys.* **32,** 4, 289–301, Jan. 1954.

It is known that the Volterra integral equation

$$\phi(x) = f(x) - g(x) \int_0^x \phi(z)\, K(x, z)dz \qquad [A]$$

[ϕ unknown and f, g, k known] may be solved numerically by a step-by-step calculation; i.e., the integral in [A] may be approximated by a sum of the type

$$\sum_{\nu=0}^{\nu=n} A(n, \nu)\phi(\nu h) \qquad [B]$$

using intervals of length h and letting $x = nh$, $z = \nu h$, then a recurrence formula results from substituting [B] in [A]. Accuracy depends on size of n and method used in obtaining $A(n, \nu)$.

Huber [*Monatshefte Math. Phys.* **47,** 240, 1939] used a linear approximation to $\phi(z)$ in order to determine $A(n, \nu)$. Author uses a quadratic expression in each two consecutive intervals for $\phi(z)$ to obtain $A(n, \nu)$ for n odd and even, with K general and a function only of $(x - z)$. A rule is suggested for determining h.

Agreement between exact solution of particular singular integral equation and approximate solution obtained by author is excellent. Unfortunately, the same equation is not solved by Huber's method. Thus it is difficut to reach a decision as to the relative accuracy of the two methods for the same expenditure of time. A comparison with Prasad's scheme [*Proc. Edinburgh Math. soc.* **42,** 46, 1924] for a nonsingular equation would also have been useful. J. L. Bogdanoff, USA

✎3089. **Kimball, W. S., Calculus of variations by parallel displacement,** London, Butterworths Scientific Publications, 1952, viii + 543 pp. 50 s.

In a series of papers over the past 17 years the author has developed several unorthodox insights into the calculus of variations, which are here gathered together in one volume. The expository style is not calculated to win many disciples. It is a very difficult book to read. There is a good deal of forward referencing so that it is hardly an exaggeration to say that it is necessary to read the whole book before the first page can be understood. The nomenclature is largely original and not always clearly defined.

The author claims that only calculus, trigonometry, algebra, analytic geometry, and simple vector analysis are necessary to absorb the book. This is largely true when he is developing his own approach; but when he makes reference to the classical approach, he appears to be writing for an expert completely familiar with every subtlety. Unfortunately, no extended critical comparison of the two approaches is ever given. Reviewer's attempt at a comparison follows.

Advantages of author's approach: (1) A (possibly) more satisfying concept of the basic process; e.g., an extremum path for an integral is one with vanishing rate of change of the integral with respect to the area swept out when any part of the path is moved parallel to itself. (2) The device of integration-by-parts is not used. (3) Certain awkward, degenerate cases appear to be treated more directly.

Disadvantages: (1) The method so far only applies to integrals containing first derivatives, thus ruling out application to beam and plate problems. (2) A number of identities and operational rules must be learned. Some of these appear quite bizarre at first; e.g., rules for partial differentiation of ordinary differentials.

Author's approach is illustrated by application to several of the classical problems in the calculus of variations (e.g., soap films, brachistochrone). S. H. Crandall, USA

3090. **Rosen, P., Use of restricted variational principles for the solution of differential equations,** *J. appl. Phys.* **25,** 3, 336–338, Mar. 1954.

Variational methods involving certain restrictions are used in the mathematical study of irreversible thermodynamics. Paper considers such variational methods and presents examples. Method can, e.g., be applied to the case where, during the flow of a gas through a shock wave, the velocity-distribution function changes appreciably over one mean free path. In such a case the usual expansion methods used in solving the transport equation cannot be used. D. ter Haar, Scotland

3091. **Huth, J. H., Mixed boundary value problems in potential theory,** *J. Franklin Inst.* **257,** 2, 121–124, Feb. 1954.

The mixed problem of determining a function, harmonic on the interior of a circle, whose value is prescribed on the upper half and whose normal derivative is prescribed on the lower half, is reduced to a Riemann-Hilbert problem. It is shown that for uniqueness of the solution, additional information is required concerning the singular behavior of the function at the points where the arcs carrying the normal derivative data intersect the arcs carrying the value of the function. This behavior is interpreted in terms of dipoles. C. Saltzer, USA

3092. **Alekseeva, O. P., Closed solution of a wave equation for a bounded medium** (in Russian), *Prikl. Mat. Mekh.* **17,** 4, 501–505, July-Aug. 1953.

Applying Laplace transformation, author solves a boundary-value problem which involves the wave equation $V_{tt} = a^2 V_{xx}$. She presents three forms of solutions: A Fourier series solution obtained from the inversion integral; a finite series form; and a closed form of the inversion integral. The advantages of a closed form are not very obvious. Boundary-value problems involving the wave equation play an important role in many engineering applications. T. Leser, USA

3093. **Mohr, E., Integration of ordinary differential equations with constant coefficients by means of the operational calculus** (in German), *Math. Nachr.* **10,** 1–49, 1953.

Paper constitutes an essential contribution to the theory of systems of linear differential equations with constant coefficients and arbitrary disturbing functions. It contains an exact discussion of all possible cases occurring in solving such systems of whatever order and shows the excellent possibilities of operational calculus.

The subject is divided into four sections. First comes mathematical formulation of the problem in the symbolism of matrixes; then follows a careful discussion of 'normal systems' having special significance in technics and physics. The remaining two parts cover almost 40 pages. They constitute the most valuable kernel of the article (from a mathematical point of view), giving a full treatise of all "singular cases."

Engineers and physicists should read this very useful paper.

It presupposes only some familiarity with the Laplace transformation and a reasonable knowledge in the theory of matrixes (characteristic numbers, elementary divisors, etc.).

V. Vodička, Czechoslovakia

3094. Southwell, R., Relaxation methods: a retrospect, *Chartered mech. Engr.* **1,** 2, 61–72, Feb. 1954.

One regrets to call this paper Sir Richard's "swan song," even though that great man has done so himself. Entitled "A retrospect," the paper contains little that is new to those who have followed the work of the author and his associates. For others, it will afford an excellent introduction to the scope and power of the relaxation method.

What is more important, in this reviewer's opinion, is its clear and just estimate of the position of mathematics in relation to engineering. Here is a point, really, of philosophy, set out by a man who is a philosopher in the original meaning of the word.

G. M. Dusinberre, USA

3095. Householder, A. S., Principles of numerical analysis, New York, McGraw-Hill Book Co., Inc., 1953, x + 274 pp. $6.

This is a scholarly and well-prepared book. One very attractive feature is the inclusion with each chapter of bibliographic notes which assist the reader in finding further information on the various topics. The book covers very recent work in the computational field and is a must for those interested in computation.

The preface indicates that there was an attempt to keep the discussion within reach of those who have had a course in calculus. This reviewer thinks the average calculus graduate would find the book rather difficult reading. Differential, integral, and other functional equations are purposefully omitted.

The book consists of two parts; the first part deals with the solution of equations and systems of equations, while the second part deals with approximation. The first part starts with a discussion of the composition of error and a brief discussion of statistical estimates. Iterative and direct methods for matrixes and linear equations are given and the various methods are compared relative to the number of arithmetical operations required. Graeffe's, Bernoulli's, and iterative methods are considered for nonlinear equations, as well as iterative and steepest-descent methods for systems of equations. Iterative and direct methods for finding proper values and vectors of matrixes are presented.

The second part begins with polynomial, trigonometric, and exponential interpolation. Least squares, finite Fourier, and Chebíshev expansions come next. Numerical integration and differentiation are presented and operational methods are used to derive the formulas.

The book terminates with a very brief treatment of Monte Carlo methods.

H. D. Huskey, USA

3096. Karpilovskaya, E. B., On convergence of an interpolation method for ordinary differential equations (in Russian), *Usp. Mat. Nauk (N.S.)* **8,** 3 (55), 111–118, 1953.

Author applies general theorems of L. V. Kantorovich concerning approximate solutions of equations containing a linear operator to the case of a nonhomogeneous linear differential equation of order $2m$ with variable coefficients $p_i(t)$ and homogeneous two-point boundary conditions. She assumes that, for all i, $|p_i^{(r)}(t_1) - p_i^{(r)}(t_2)| < L|t_1 - t_2|^\alpha$, where r is an integer and $0 < \alpha \leqq 1$. Then, using the collocation method of approximating the solution at n points inside the interval, she finds an error of order $O(\ln^2 n/n^{r+\alpha})$ when the collocation points are zeros of the nth degree Chebíshev polynomial, and $O(1/n^{r+\alpha-1})$ when they are zeros of the nth degree Legendre polynomial.

Courtesy of Mathematical Reviews W. E. Milne, USA

3097. Miller, K. S., and Murray, F. J., A mathematical basis for an error analysis on differential analyzers, *J. Math. Phys.* **32,** 2/3, 136–163, July/Oct. 1953.

Three kinds of errors are considered: one due to the mechanics of the machine; another due to introduction of incorrect parameters or spurious signals; and the fact that the machine attemps to solve differential equations of higher order due to the imperfect representation of the original problem on the machine. The effect of these errors on the solution, in its various regions, is related to the differential effects of each error. The procedure, however, is quite involved.

G. King, USA

3098. Crease, B. A., and Tucker, M. J., A note on an improved planimetric method of harmonic analysis, *Brit. J. appl. Phys.* **5,** 4, 143–146, Apr. 1954.

Paper is an extension of method of AMR **6,** Rev. 747, which is regarded as planimetric integration of function to be analyzed, multiplied by a square wave instead of a sine wave. Authors use more complex step-type modulating functions to approximate more closely to a sine wave and thus reduce required corrections due to higher-order harmonics. A worked example is included.

K. H. Griffin, England

3099. Epheser, H., and Stallmann, F., Conformal mapping of a parallel strip with semicircular notch (in German), *Arch. Math.* **3,** 4, 276–281, 1952.

Paper deals with an approximate solution of the problem. Functions of two pairs of sources give the conformal mapping of the semicircle configuration into a half plane. Strength and location of the sources are the two free parameters, a suitable choice of which allows approximation of the semicircular notch. A comparison with exact solution by Stallmann shows that results given in figures and tables are in very good agreement (less than 1% error) for small radius of notches and are satisfactory for practical use if higher radius is wanted.

F. Keune, Sweden

3100. Epheser, H., and Stallmann, F., Conformal mapping of a rectangle with a half circle notch (in German), *ZAMM* **33,** 8/9, 268–269, Aug./Sept., 1953.

Continuing another report (see preceding review), the conformal mapping of this configuration into a half plane is given by an elliptic integral of third class. For determination of the parameters, the integral is written in theta series. Authors believe that given method is more accurate than other approximations and can be developed for other forms of notches.

F. Keune, Sweden

3101. Zakarin, A., On a method of successive approximations in conformal mapping (in Russian), *Izv. Akad. Nauk Kazah. SSR* **1951,** no. 62, *Ser. Mat. Mekh.* **5,** 104–118, 1951.

A method of successive approximations is used to construct an analytic function which maps the unit circle $|z| < 1$ conformally on a simply connected nearly circular region. The successive approximations are based on the familiar integral representation of the sum of a conjugate trigonometric series. The author's method is compared, in some special cases, with that of L. V. Kantorovich ["Conformal mapping of simply and multiply connected regions," ONTI, Leningrad-Moscow, 1937, pp. 5–17].

Courtesy of Mathematical Reviews W. Seidel

3102. Tye, W., The arithmetic of airworthiness, *J. roy. aero. Soc.* **8,** 519, 195–208, Mar. 1954.

Parallel operation of elements subject to failure (motors, generators, pumps, vacuum tubes, etc.) to achieve reliability is

studied by elementary probability theory. Theory of compound probabilities is sketched, and dependence of system failure rate on component failure rate is derived and applied to economics of system design. Independence of failure rates is assumed; practical consequences of this assumption are discussed; e.g., a part which serves two or more parallel components must be as reliable as primary structure; failure of one component must not overstress the remaining components.

Effect of running time, length of service, and aging are discussed and connection with problem of measuring failure rates is sketched.

Paper is expository. Reviewer considers it an excellent and concise sketch of main problems and elementary methods of attack. Although author considers only aircraft components, problems and methods are quite general. See also: D. M. Boodman, Reliability of airborne radar equipment, *J. Oper. Res. Soc. Amer.* **1**, 2, 39–45, Feb. 1953; D. J. Davis, An analysis of some failure data, *J. Amer. stat. Assn.* **47**, 113–150, June 1952.

A. A. Brown, USA

3103. **Davis, R. C., On the detection of sure signals in noise,** *J. appl. Phys.* **25**, 1, 76–82, Jan. 1954.

"Sure signals" are defined as nonrandom signals of known mathematical form. Paper presents a derivation of exact conditions under which a predetection filter which maximizes the probability of detection coincides with the linear filter which maximizes the output signal-to-noise ratio.

The topic of optimum pulse shape for fixed pulse energy is discussed and an infinite system of linear equations for the Fourier coefficients of the desired signal is obtained.

T. E. Caywood, USA

3104. **Bellman, R., Bottleneck problems and dynamic programming,** *Proc. nat. Acad. Sci. Wash.* **39**, 10, 947–951, Oct. 1953.

The following problem with certain linearity hypotheses is reduced to a functional equation, and a method of solving the equation is outlined.

"At some initial period we possess a quantity x_1 of steel and a capacity x_2 of steel production, with the privilege of dividing the quantity x into three parts, y_1, y_2, y_3, where y_1 is to be used to increase the capacity, y_2 to be used together with the present capacity to produce more steel, and y_3 to remain in the stockpile. Given that this allocation and production process continues for a fixed number of time periods and given the increase in capacity determined by x_1 and y_1 and the increase in the quantity of steel determined by x_2 and y_2, the question is to determine the allocation policy which maximizes the quantity of steel in the stockpile at the end of the final period."

D. Blackwell, USA

3105. **Bellman, R., Some functional equations in the theory of dynamic programming,** *Proc. nat. Acad. Sci. Wash.* **39**, 9, 1077–1082, Sept. 1953.

Solutions are given for certain functional equations which arise in connection with inventory policies and other problems involving a sequence of decisions which are to be made so as to maximize a specified function.

D. Blackwell, USA

3106. **Smith, J. J., Tables of Green's functions, Fourier series, and impulse functions for rectangular co-ordinate systems,** *Trans. Amer. Inst. elec. Engrs.* **70**, 22–30, 1951.

The paper gives a collection of Green's functions for the solution of boundary-value problems in the Laplace and Poisson equations, the heat equation, and the wave equation, in one-, two-, and three-dimensional rectangular regions. On the boundaries any linear combination, with constant coefficients, of the unknown function and its normal derivative is to be prescribed. Unbounded regions are included. Green's functions are listed as infinite trigonometric series or integrals, generally nonconvergent. Relations between those series and orthogonal series representations of functions and of impulse functions are tabulated. Explanations of the complex notation used here are not easy to find.

Courtesy of Mathematical Reviews R. V. Churchill, USA

Mechanics (Dynamics, Statics, Kinematics)

(See also Revs. 3086, 3215, 3216, 3300, 3303, 3429)

3107. **Béghin, H., Course of theoretical and applied mechanics. I, II [Cours de mécanique théorique et appliquée],** Paris, Gauthier-Villars, 1952, viii + 551 pp.; 1951, 328 pp. 7200 Fr.; 3600 Fr.

Mechanics as a deductive science can be developed on a postulational basis, starting with a minimum number of axioms and then using combinations of them in such a way as to establish certain general laws in a form suitable for applications. On the other hand, considering mechanics as an experimental science, one can start directly with a formulation of such general laws, inductively derived from terrestrial or solar-system experience, and indicate the principles which constitute the basis of these laws. The first approach is most satisfactory from a philosophical point of view; the second is that chosen by the author, keeping in mind the needs of future engineers.

This book reproduces author's lectures given at the École Polytechnique, Paris, beginning in 1945. The subdivision into two volumes corresponds to the program of studies of mechanics at this institution.

Assuming a knowledge of mechanics at the level of a French lycée, the author has endeavored to give as easy an exposition as possible, advancing step by step from the simple toward the more complicated, and never losing contact with real experience. In this way he arrives at the analytical methods based on Lagrange's and Appell's equations, and the concepts of analytical mechanics underlying modern physical theories. On the other hand, he is concerned with problems of fundamental mechanical significance and important engineering applications. The latter constitute the first third of the second volume. The rest of this volume concerns mechanics of continua. This consists of two parts: fluid mechanics and mechanics of elastic solids; both are given with important practical applications.

Special care is taken in introducing various mechanical quantities. In particular, the concept of work, which becomes very delicate in mechanics of continua, is defined in such a way that the theorem of virtual work appears in all its generality as a corollary of the fundamental law of mechanics.

A certain number of examples illustrating the more difficult ideas and of interest to engineering students are worked out; there are 183 exercises for the student. The presentation is rigorous and vivid.

The book is written in the best tradition of author's eminent predecessors, such as E. Jouget, L. Lecornu, P. Painlevé, and Ch. Platrier, and is distinguished by orginality of thought and presentation. In the opinion of the reviewer, this book deserves an honorable place among the textbooks of mechanics.

A selection of chapter and section headings follows. Vol. I: I. Kinematics of a particle and a solid. Some mechanisms. Graphical kinematics. II. Geometry and kinematics of masses. III. Laws of universal mechanics. IV. Momentum theorems. V. Galilean frames. Some practical frames. VI. Contact actions. VII. Some simple problems of terrestrial mechanics (solids, fluids, strings). VIII. Determination of motion of rigid

bodies by initial conditions. Indeterminateness. Impossibilities. IX. Work. Output. X. Mechanical and electromagnetical units. XI. Mechanics of a particle. Equivalence of work and kinetic energy. Reversibility. Oscillations with linear and nonlinear characteristics. Self-sustained oscillations. Motion of a heavy particle through air. Central forces. Constrained motion of a particle along a curve and in a surface. Spherical pendulum. Motion relative to the earth. XII. Theorem of virtual work. Theorem of equivalence of work and kinetic energy. Applications. Fixed machines. Movable machines. Tractor. Cyclist. Swing. XIII. Statics and dynamics of strings. XIV. Lagrange's equations. Extension to rolling motions (nonholonomic constraints) and certain deformable bodies. Control of mechanisms. XV. Impact. Carnot's theorem. Application of Lagrange's equations. Collision with friction. XVI. Small oscillations about equilibrium. Stability. Effect of resistance and gyroscopic forces. Oscillations about steady motion. Stability. XVII. Appell's equations. XVIII. Concepts of analytical mechanics. Canonical equations. Jacobi's equation. Hamilton's, Maupertuis' and Gauss' principles. Vol. II: I. Rotation of rigid bodies. II. Gyroscope. Gyroscopic forces. Application of Lagrange's equations. Industrial applications of a gyroscope. III. Energy. Applications to machines. IV. Regulation of motion of a machine. V. Geometry and kinematics of continua. VI. Internal stress. Equilibrium and motion of a continuum. VII. Equilibrium of fluids. Floating bodies. VIII. Motion of perfect fluids. Transformation of the equations of motion. Vortex motion. Euler's and Bernoulli's theorems. Flow of liquids and gases. Hydraulic turbine. Steam turbine. IX. Irrotational motion of an incompressible fluid. Laplace's equation. d'Alembert's paradox. X. Two-dimensional irrotational motion of an incompressible fluid. Complex potential. Conformal representation. Streaming motion past a cylinder. Blasius' theorem. Kutta-Zhukovski's theorem. Zhukovski's transformation. XI. Vortex motion. Resistance of fluids. Aerofoil of finite span. XII. Propagation of waves. Discontinuities. Shock waves. Quasiwaves. Gerstner's trochoidal wave. XIII. Viscosity. Turbulence. XIV. Equilibrium of elastic solids. Stress and strain. Internal potential. Resistance. Mohr's circles. Applications. Problem of Saint-Venant. Problem of elastic buckling. XV. Resistance of materials. XVI. Theorems of work (Clapeyron, Castigliano, Maxwell, Betti). Application to hyperstatic systems. XVII. Small motions of elastic isotropic bodies. XVIII. Similarity in mechanics. Applications. Two appendixes. E. Leimanis, Canada

3108. Freeman, I. M., Rectangular plate pendulum, *Amer. J. Phys.* **22,** 4, 157–158, Apr. 1954.

A uniform rectangular plate is arranged so that it oscillates in its own plane around either one of two axes, one at the center of each edge. The analysis shows that there is a particular ratio of the lengths of the two sides (in addition to unity) for which the two periods are equal, and still another ratio giving the minimum period. These computations check satisfactorily with experiment. From author's summary

3109. Chetaev, N. G., On stability of rotation of a rigid body with a fixed point in Lagrange's case (in Russian), *Prikl. Mat. Mekh.* **18,** 1, 123–124, Jan.-Feb. 1954.

The necessary and sufficient condition for stability of a sleeping top is standard textbook material ($C^2r_0^2 \geqslant 4Amgz$). The author succeeds in proving its sufficiency by a less direct method employing Lyapunov's criterion (existence of a positive definite function of the perturbations). Routh ["Advanced rigid dynamics," 1905, arts. 214 and 214c] solves the problem for uniform precession (not just rotation) about the vertical, the moments of inertia and the position of the mass center being unrestricted.

A. W. Wundheiler, USA

3110. Rihosek, J., Causes of stalling of rolling wheels (in German), *Z. Öst. Ing.-Arch.-Ver.* **98,** 19/20, 189–192, Oct. 1953.

Due to sharp braking in railway operation, heavy wear can occur on the wheel rim while sliding occurs. This often happens in the case of long freight trains since the introduction of brake systems extending to all cars. The locking of an individual wheel occurs when the frictional power of sliding friction between the wheel and the rail is smaller than between the wheel and the brake shoe. Iced or oily rails facilitate the locking of wheels. The best way to avoid wheel locking would be an automatically controlled device which would protect against the braking force exceeding 70% of the weight exerted on the wheel. Locking sometimes occurs during the start when the brakes are not released at the right time. The reason for this is discussed and a valve which should protect against initial locking is described.

L. Föppl, Germany

3111. Tolle, O., The inertia pole curve of the connecting rod of a slider-crank mechanism (in German), *Ing.-Arch.* **21,** 5/6, 365–367, 1953.

The inertia pole is the common point of intersection of the resulting inertia forces for all possible states of acceleration. The inertia-pole curve denotes the locus of the instantaneous poles during the motion. Author simplifies results of Federhofer [AMR **4,** Rev. 4375] for the case where the square of the ratio between the lengths of the crank and the connecting rod may be neglected. The inertia-pole curve then becomes an ellipse.

A. I. van de Vooren, Holland

3112. Gross, W., Computation of Newtonian attraction between two coaxial homogeneous disks (in Italian), *Cons. naz. Ricer.* no. 365, 9 pp., 1953. (Contributed by the Istituto Nazionale per le Applicazioni del Calcolo at the Fourth Congress of the Italian Mathematical Society.)

3113. Schütte, K., Determination of the elements of the orbit when the initial velocity vector is given (in German), *Weltraumfahrt* nos. 4, 1; 98–107, 13–23, Oct. 1953, Jan. 1954.

This long paper contains nothing more than the determination of the longest axis and the eccentricity of the ellipse in the problem of the two bodies, when the initial velocity is given in size and direction. ("Da für dies Problem keine Lösung bekannt zu sein scheint, wurde eine eigene Methode entwickelt.") The calculations are extremely detailed because the author does not make use of Kepler's second law. O. Bottema, Holland

Servomechanisms, Governors, Gyroscopics

(See also Rev. 3139)

3114. Flügge-Lotz, I., Discontinuous automatic control, Princeton, N. J., Princeton Univ. Press, 1953, vii + 168 pp. $5.

The first two chapters acquaint the reader with the dynamical significance of the discontinuous control; reduction to the minimum number of parameters and continuity of solutions (although a lack of analyticity at some points) are indicated. Chaps. 4 and 5 are fundamental; here the piecewise analytic representation of the phase trajectories is clearly presented, and it is shown how the special features of the problem such as "end points,"

"rest points," etc., account for this representation. Chap. 4 deals with position control, and chap. 5 with velocity control. Author also shows that, under special conditions, periodic solutions are possible. Chaps. 6 and 7 treat additional questions arising from the imperfections in control systems; among these the effect of time lags is investigated. Part III treats the case when the body to be controlled has more than one degree of freedom. Author starts with the differential equations of the uncontrolled process into which the discontinuous control action is ultimately fitted. Numerous calculations and graphical constructions accompany this discussion.

The book is written in an interesting and logical manner and is recommended not only to those who are interested in the somewhat narrow field of guided missiles but also to a wider group of readers whose interest lies in the general approach to the investigation of the piecewise analytic phenomena on the basis of the phase plane analysis. It is regretted that the author did not specify the limitation of the validity of the differential equations from which the problem is started in part III; as these equations are linear, the discussion holds only for the subsonic range. It is obvious that, for higher speeds, the conclusions may be entirely different. This, however, does not react in any manner on the method of the piecewise-analytic diagrams considered *per se*.

N. Minorsky, France

3115. **Oppelt, W., Handbook of technical regulation processes [Kleines Handbuch technischer Regelvorgänge],** Weinheim Bergstr., Verlag Chemie, GMBH, 1954, 448 pp., 353 figs., 110 tables. DM 31.80.

This book is a revised one-volume edition of two previous texts by the same author and contains a very thorough analysis of continuous regulation. Chaps. 1, 2, and 3 are general and introductory. Chap. 4 is a study of the dynamics of the machine or process to be regulated, chap. 5 of the regulator proper, and chap. 6 of the closed loop which contains both. Chaps. 7, 8, and 9 are short treatments of multiloop and discontinuous regulators and of models. Chap. 10 is an atlas of 35 pages of diagrams, each page dedicated to a specific combination of machine and regulator, containing four families of loci in the complex plane and the four corresponding families of transients.

There is a very thorough and well-organized bibliography. Author has been at pains to incorporate the modern American methods of servomechanism analysis into the older and narrower point of view of regulation proper, to which this text faithfully holds. To the reader familiar with American postwar literature this book will teach nothing new; it is, however, recommended for the unique thoroughness with which it presents applications of each specific type of transform function to electrical, mechanical, hydraulic, and pneumatic devices. The richness and quality of the illustrations alone would make the book worth while. All in all, a most valuable tool for the regulation specialist.

P. Le Corbeiller, USA

3116. **Fuller, A. T., Control systems with quasi-critical damping,** *Brit. J. appl. Phys.* **5,** 5, 174–179, May 1954.

Quasi-critical damping of a control system is said to occur when "the response to a step change of input is such that the output eventually reaches a regime in which it just fails to overshoot its final equilibrium value, this regime extending to infinite time."

Using this definition, author shows a system to be quasi-critically damped when two or more of the poles of the closed-loop transfer function have equal negative real parts, with at least one pole real. He then uses this criterion to develop a relation among the various lags of the system for quasi-critical damping, and finally obtains expressions for the loop gain.

Author's results indicate that, for practical systems, one open-loop lag must predominate and a reasonably accurate approximation for loop gain at quasi-critical damping is (0.3) × ratio of major lag to sum of minor lags.

W. A. Wolfe, Canada

3117. **Gold, H., and Otto, E. W., An analytical and experimental study of the transient response of a pressure-regulating relief valve in a hydraulic circuit,** *NACA TN* 3102, 54 pp., Mar. 1954.

A straightforward hydraulic relief valve is analyzed with the help of electrical analog circuits. Problem is first linearized by assuming changes in variables to be small perturbations from steady state. Response is derived for simple circuit containing resistance and relief valve, supplied by fixed capacity pump with internal losses, when circuit is suddenly closed or opened. Hydrodynamic forces on valve (which may lead to effective negative damping—see AMR 6, Rev. 527) and return line resistance are not considered. Effect of capacity and fluid mass in lines is discussed but not analyzed. Calculated responses are compared with experimental results, agreement being poor on natural frequency, but quite fair on stability, which is by far the more important result. Simple criteria are given for adequate valve stability in elementary cases; stability need not depend on valve damping. Stability varies with flow, unless this effect is compensated by specific nonlinear relationship between orifice area and valve travel.

Although analysis is elementary, it could be easily extended to more complex cases, and reviewer considers it to be a very useful contribution to an important practical problem. Reviewer suggests that complex cases could be more easily dealt with by frequency-response method, not requiring solution of transient response equation. It could also be pointed out that relief valve is a closed-loop system and that stability criterion limitation on orifice area per unit travel is, in effect, limitation open-loop gain of system, as is well known in servo theory.

R. Hadekel, England

THE FOLLOWING PAPERS (REVS. 3118–3128) WERE PRESENTED AT THE Frequency-Response Symposium, ASME Ann. Meet., New York, Dec. 1953.

3118. **Oldenburger, R., Frequency-response data presentation standards and design criteria,** Pap. 53—A-11, 16 pp.

The standards are recommended by the ASME-IRD Dynamic Systems Committee. The Committee recommends that magnitude curves be plotted on logarithmic coordinates, and phase on the linear scale versus frequency on the log scale. Further recommendations involve transfer functions, measurements, nonlinearity, ambient effects, and other factors. The paper was written with the technician in mind as well as the automatic control engineer and scientist.

From author's summary by R. M. Stewart, USA

3119. **St. Clair, D. W., Erath, L. W., and Gillespie, S. L., Sine-wave generators. A survey of pneumatic, mechanical, and electrical devices for obtaining frequency-response data,** Pap. 53—A-12, 7 pp.

Data are given on pneumatic, mechanical, and electrical sine-wave generators which are or can be used to impose the "wiggle" necessary for the taking of frequency-response data in the industrial-control field. The high points are covered from a functional rather than a theoretical viewpoint and a reference list is presented to assist those interested in additional information.

From authors' summary

3120. **Fuchs, A. M., Bibliography of the frequency-response method as applied to automatic feedback-control systems,** Pap. 53—A-13, 9 pp.

3121. Macmillan, R. H., Analysis of regulating systems with particular reference to speed control, Pap. 53—A-15, 7 pp.

This article deals with three different topics: (a) A critical review of present-day methods of handling systems for process control, position control, and regulation, with a valuable bibliography. There seem to be a few discrepancies between the numbering of items in the text and in the bibliography. (b) A study of a gas-turbine speed governor, fully but succinctly treated. (c) A plea for introducing the elements of the theory of control in the senior year of undergraduate engineering studies. This article is too condensed to serve as an introduction, but contains some very interesting remarks and references for those already conversant with the subject. P. Le Corbeiller, USA

3122. Hall, A. C., Application of frequency-analysis techniques to hydraulic control systems, Pap. 53—A-16, 7 pp.

Author limits discussion to dynamical properties of a valve-and-motor servomechanism. No demonstration is given of linearization of original irrational equations. Network is adopted as an electrical analogy for hydraulic valve motor to study frequency response. Inductance similarly represents servo loads.

Methods outlined have been developed during past six years. Paper is very intelligible, and author emphasizes that servo systems with natural frequencies of better than 100 cps have been successfully synthesized. Acceptable approximation of linearity is based upon small fluid-flow changes in comparison with steady-state flow. J. Carrizo Rueda, Argentina

3123. Oldenbourg, R. C., and Sartorius, H., A uniform approach to the optimum adjustment of control loops, Pap. 53—A-18, 9 pp.

A comprehensive paper which sets out briefly but lucidly the considerations underlying determination of optimum settings for the variable parameters in a control loop and applicable to both process control systems and servomechanisms. Response to an isolated disturbance is considered first, and choice of a step function or an impulse function is discussed. Linear and quadratic measures of error are discussed. Linear measure of error is area enclosed between deviation recovery curve and the time axis, and linear optimum criterion corresponds to a minimum value of this area. This has meaning only when recovery curve is not oscillatory; for the oscillatory case the quadratic measure of error is applicable, the area enclosed between square of deviation and the time axis. A minimum value of this area gives the quadratic optimum criterion. For a loop subject to continuous disturbances, authors choose time average of deviation as quantity to be minimized, and show that the process of finding optimum adjustments is same as for isolated disturbances. The quadratic criterion, which insures a fast oscillatory recovery, requires so much calculation that authors propose a "practical optimum criterion" that is much simpler to use and gives optimum settings that compare favorably with those derived from quadratic criterion. The three criteria are applied to a typical example and response curves are compared. E. Giffen, England

3124. Loeb, J. M., Recent advances in nonlinear servo theory, Pap. 53—A-19, 8 pp.

Author refers to previous work of Dutilh and Kochenburger on servos consisting of nonlinear element (e.g., contactor) with response varying with amplitude but independent of frequency, followed by linear filtering element such as a high inertia motor armature. This allows harmonics in output to be neglected. Method is extended to general case of nonlinear servos incorporating a filtering element. For such systems, open-loop frequency response can be written down for any assigned signal amplitude. This gives family of response loci for various amplitudes, to which Nyquist criterion can be applied. All loci may be stable. If not, for one particular amplitude a steady oscillation can in theory be maintained, but this will be truly stable only if small perturbation in amplitude results in return to equilibrium value. Conditions for this are examined and analytical criteria derived. Method is applied to analysis of contactor-motor servo, with contactor having a definite operating threshold. Method is also stated to be applicable to nonlinearities of "hereditary" type, such as magnetic hysteresis, Coulomb friction, and backlash.

R. Hadekel, England

3125. Pélegrin, M. J., A statistical approach to servomechanisms and regulators, Pap. 53—A-20, 9 pp.

Problem: Application of statistical methods to feedback control systems subject to noise disturbances and command signals describable only by statistical means.

Reviewing basic statistical techniques of generalized harmonic analysis, author applies them to the synthesis of corrective networks for closed loop systems subject to random load disturbances and noise-free commands. The autocorrelation function of the output of a relay subject to random signals is presented. An exhaustive study of a speed regulator consisting of a variable inertia flywheel subject to a constant load and then a random load follows.

Reviewer believes this work is significant in part, but article is unclear, abounding in many undefined terms and parameters. Little verification is presented for some of the conclusions, and some errors of fact exist. In part, the paper is merely a summary of previous work by the author. The section on the variable inertia regulator is novel but incomplete as regards the statistical problem. L. A. Gould, USA

3126. Aikman, A. R., Frequency-response analysis and controllability of a chemical plant, Pap. 53—A-22, 9 pp.

The practical frequency-response analysis of two types of chemical plant units, and the adjustment of the automatic controllers, are described. Available information on the magnitude, form, and location of disturbances is used to illustrate the effect of these factors on the quality of control actually obtained, and to emphasize that these factors are at least as important as the over-all characteristics of the plant. Even when all information on the disturbances is available, their effect on the quality of automatic control is not always easy to calculate, especially if the system has distributed parameters, but a description is given of an approximate calculation method which yields results of the right order of magnitude in many practical cases.

From author's summary

3127. Chestnut, H., Approximate frequency-response methods for representing saturation and dead band, Pap. 53—A-25, 16 pp.

Paper gives a method whereby characteristics of nonlinear elements having saturation or dead-band properties may be described by an "equivalent linear coefficient." This coefficient is variable in nature, depending upon ratio of magnitudes of input and saturation value or dead zone of nonlinear element. This method does not provide an exact solution. However, by employing a systematic series of coefficients, useful qualitative results are obtained.

Reviewer feels paper to be a useful addition to frequency-response analysis of servomechanisms. W. A. Wolfe, Canada

3128. Thomas, C. H., Stability characteristics of closed-loop systems with dead band, Pap. 53—A-26, 16 pp.

Paper presents a method of analyzing closed-loop systems when presence of a dead band causes self-sustaining cyclic motion. Analysis considers in detail a mechanical linkage involving spring

action, inertia, and viscous damping. Elements incorporating dead bands are replaced by "equivalent systems," whose transfer characteristics are functions of signal amplitude and frequency. Stability criteria are developed and conditions are established under which self-sustained oscillations occur. Frequency response methods are employed throughout. Reviewer feels paper to be a useful contribution to frequency-response method of analysis of closed-loop systems. W. A. Wolfe, Canada

Vibrations, Balancing

(See also Revs. 3083, 3108, 3140, 3264, 3323)

3129. **Crede, C. E., Natural frequency of a nonlinear system subjected to a nonmassive load,** *Trans. ASME* **76,** 1, 117–119, Jan. 1954.

Paper discusses change in natural frequency (for small displacements) of a nonlinear spring (a rubber vibration isolator for which the force-deflection characteristic is known empirically) under a sustained constant acceleration. It should be pointed out that the mass of the rubber isolator is assumed negligible in the derivation (further, the negative sign in Eq. [8] is a misprint). Results are shown in nomographic form. Appendix by D. C. Kennard, Jr., discusses appearance of additional resonance frequencies in a nonlinear spring system when the displacements are large. J. J. Gilvarry, USA

3130. **Schaffner, J. S., Almost sinusoidal oscillations in nonlinear systems, Part III: Transient phenomena,** *Univ. Ill. Engng. Exp. Sta. Bull.* 421, 38 pp., Nov. 1953.

This bulletin is the third in a series of three bulletins dealing with a number of oscillatory problems. In the first two bulletins emphasis was placed on steady-state oscillations, while in this bulletin the discussion is concerned with nonsteady-state or transient oscillations. The oscillatory phenomena discussed here are parametric excitation, synchronization, simultaneous oscillations, and amplitude limitation by means of lamps.

From author's summary

3131. **Baron, M. L., and Bleich, H. H., Tables for frequencies and modes of free vibration of infinitely long thin cylindrical shells,** *J. appl. Mech.* **21,** 2, 178–184, June 1954.

See AMR **7,** Rev. 1006.

3132. **Bleich, H. H., and Baron, M. L., Free and forced vibrations of an infinitely long cylindrical shell in an infinite acoustic medium,** *J. appl. Mech.* **21,** 2, 167–177, June 1954.

See AMR **7,** Rev. 1301.

3133. **Szegö, G., On the vibrations of a clamped plate,** *Atti Quarto Congr. Unione Mat. Ital., Taormina, 1951,* **II,** 573–577. Casa Editrice Perrella, Roma, 1953.

Rayleigh has conjectured that among all clamped plates with a given area, the circular plate has the least first eigenvalue. The conjecture was proved by Szegö under the assumption that the corresponding eigenfunction has no zeros. This is true if Green's function for the plate or any of its iterates is positive; but it is announced that recent simple examples by Loewner, Szegö, and Garabedian show there are domains for which this is not true. *Courtesy of Mathematical Reviews* L. Gårding, Sweden

3134. **Warburton, G. B., The vibration of rectangular plates,** *Chartered mech. Engr.* **1,** 1, 22–23, Jan. 1954.

The frequencies of free transverse vibrations of rectangular plates for all combinations of free, freely supported, and fixed edges are considered. From author's summary

3135. **Thomson, W. T., Impulsive response of beams in the elastic and plastic regions,** Univ. of Calif., Los Angeles, 16 pp., 11 figs., 1953.

If the free response of a clamped beam to an impulse is considered as the forced response of a pinned beam under action of the impulse and the end moments developed in the clamped beam, and if these end moments are the maximum moments occurring, then limiting these moments gives the required response through at least the first elastic-plastic transition. The analog method used develops beam displacement in terms from a series of elastic normal modes. Reviewer believes nonuniform convergence of the series and consequent low accuracy for the method are to be expected in the plastic range.

C. M. Ablow, USA

3136. **Niordson, F. I. N., Vibrations of a cylindrical tube containing flowing fluid,** *Trans. roy. Inst. Technol. Stockholm* no. 73, 28 pp., 1953.

Several small-vibration problems are solved, relating to a long elastic tube on equally spaced supports where the tube is either filled or surrounded by inviscid, compressible fluid. Complete differential equations are given for radial, peripheral, and axial deformation of the tube subject to fluid pressure. Through a boundary condition at the wall, these are coupled with the linearized equations for the fluid velocity potential. However, the two systems are mathematically decoupled and a procedure developed for solving the general vibration problem by assuming the velocity potential to contain a separated function of the radial coordinate only.

Using certain reasonable approximations based on relative size of frequencies of lateral, longitudinal, and torsional vibrations, solutions of two particular cases are developed in detail: (1) Vibrations of a full tube when the fluid has negligible axial motion relative to the tube; and (2) bending vibration when the fluid flows along with appreciable velocity U. Practical application of the first solution to a steel penstock indicates no effect of compressibility of water on low-frequency bending vibrations, but some influence on more rapid radial vibrations. A simple modification of this solution is shown to describe motion of an empty tube surrounded by fluid. The second solution confirms Housner's result [AMR **5,** Rev. 3319] that reasonable U-values produce only a slight reduction in bending frequencies. A (very high) critical U is identified beyond which fluid inertia forces cause lateral instability of the tube.

Interesting light is thrown on the mathematical nature of the problem of lateral vibration with flowing fluid by replacing the beam by a vibrating string under tension. Two critical flow rates are found, one above which the plucked-string problem cannot be solved, and a higher one above which the differential equation changes from hyperbolic to elliptic type and yields no stable solutions whatever. H. Ashley, USA

3137. **Pöschl, Th., On the principal vibrations with finite amplitudes** (in German), *Ing.-Arch.* **21,** 5/6, 396–398, 1953.

Supplement to AMR **6,** 741. Author states that the differential equation of the "limit curves" may be considered a "condition of transversality for the variational problem" (attributed to D. Hilbert, but without reference to a specific part of Hilbert's work). K. Klotter, USA

3138. **MacNeal, R. H., and Benscoter, S. U., Analysis of sweptback wings on Cal-Tech analog computer,** *NACA TN* 3115, 80 pp., Jan. 1954.

Deflections and all internal forces under concentrated static loads have been calculated by means of the CalTech direct

analog computer for two 45° swept wings of aspect ratio 3. Some vibration modes are also shown. Authors show direct electrical analogies. Results are given as series of tabulated charts and graphs. Authors find that omission of shearing strains produces errors in deflections of 10% or less. Assumption of rigid ribs produces errors of 25% in distribution of spanwise twisting moments, rib bending moments, and shears in the ribs and spars.

A. C. Block, USA

3139. Campbell, G. A., Katz, E. F., and Raninen, A. B., How mathematical reasoning leads way to design of round gimbals to predictable stiffness, *G. M. Engng. J.* **1,** 5, 26–30, Mar.-Apr. 1954.

Authors find the stiffness of gimbal ring by strain energy; they indicate Holzer solution for natural frequency of gimbal mounted table. Experimental values check stiffness to 12%.

R. Plunkett, USA

Wave Motion, Impact

(See also Revs. 3092, 3106, 3196, 3253, 3273, 3274, 3284, 3345, 3432, 3433)

3140. Ghosh, S. K., Energy absorbed by a bar under a compressive impact by an elastic load. IV, *Indian J. theor. Phys.* **1,** 2, 73–78, Sept. 1953.

This paper is the fourth in a series, written partly in collaboration with M. Ghosh [AMR **5,** Rev. 354; **6,** Rev. 2174; **7,** Rev. 1395], on the dynamics of longitudinal impacts between a moving load B and a stationary bar A which is fixed at the end remote from the impact. In the present paper, the ratio of the kinetic energy lost by B during impact to its initial kinetic energy is calculated as a function of (a) the longitudinal displacement w_l of the struck end of A, (b) the ratio of the masses of A and B, and (c) the ratio E_2/E_1, where E_1 is the value of Young's modulus of A and E_2 is the stiffness, i.e., the restoring force per unit compression, of B. Curves are given for a specific set of parameters and the curve for w_l is compared with that obtained experimentally by Habib [AMR **2,** Rev. 634] in high-speed compression tests on copper; the curves agree qualitatively.

R. M. Davies, Wales

3141. Ripperger, E. A., The propagation of pulses in cylindrical bars—an experimental study, Proc. First Midwestern Conf. Solid Mech., Engng. Exp. Sta., Univ. of Ill., 29–39, Apr. 1953.

Author extends Davies' investigation [AMR **2,** Rev. 988] on the propagation of pulses along cylindrical bars. The extensive test program consists of surface strain measurements along bars of $^1/_8$-in., $^1/_4$-in., $^1/_2$-in., and 1-in. diameter, under longitudinal impact with durations ranging from 4.4×10^{-6} to 34.3×10^{-6} sec obtained by dropping of steel balls of different diameters. Author concludes that in order for a pulse to be transmitted along a bar without serious reduction in amplitude or change in form, it should have a duration of at least eight times the time required for a pulse to travel a distance equal to the diameter of the bar. Author also points out a technique for eliminating the bending wave, which is one cause of the unreliable measurements.

T. H. H. Pian, USA

3142. Das Gupta, S. C., Propagation of Rayleigh waves in soils, *Geofis. pura appl. Milano* **25,** 13–16, 1953.

Propagation of Rayleigh-type waves in soils is considered. It is a well-known fact that soils do not behave like an ordinary isotropic elastic medium, where the ratio of Young's modulus to the modulus of rigidity is much less than that in sandy soils. Considering the velocity of the Rayleigh-type wave as less than that of distortional wave (which is an observed fact), a probable value of this ratio is determined; also assuming the value of this ratio based on some experimental data, the velocity of wave propagation in the medium is deduced. From author's summary

3143. Burns, J. C., Long waves in running water, *Proc. Camb. phil. Soc.* **49,** part 4, 695–706, Oct. 1953.

The effects on wave velocity in shallow-water theory of vorticity in the main stream and velocity distribution as a function of depth are considered. In the analysis of a two-dimensional disturbance, the first assumption is that the vertical acceleration of the fluid may be neglected so that the pressure is given by the hydrostatic law. The momentum equation is written in terms of this assumption with the appropriate boundary conditions, i.e., the vertical component of the disturbance velocity is zero at the bottom and equals the rate of increase of total depth at the surface. The continuity equation is integrated using these boundary conditions. The assumption is made that the product of the depth and the partial derivative of the vertical disturbance velocity with respect to horizontal displacement is small, compared to the horizontal component of the disturbance velocity. Under this condition, the integrated continuity equation, momentum equation, and Hemholtz's vorticity equation are expressed in terms of the bottom disturbance velocity, free surface, and vorticity.

The special case is considered when the main stream has constant vorticity and the velocity depends linearly on the depth. Results show that the wave velocity is greater than the value given by classical theory, in which the vorticity is assumed zero. In addition, the plus and minus values of wave velocity relative to the bottom of the stream do not lie between the velocities at the bottom and the surface, respectively.

In order to consider more general velocity distributions, the differential system is linearized. The final equation connecting the wave velocity c relative to the bottom with the main stream velocity distribution $U(y)$ is ${}_0\int^h (U - c]^{-2}\, dy = 1/g$. Constant, linear, and parabolic distributions are considered. Results for the parabolic show that c has one positive and one negative value, and the upstream and downstream velocities relative to the mean flow are each greater than $(gh)^{1/2}$. A graph is included.

For general $U(y)$, subject to certain restrictions, it is shown that two values of c exist which do not lie between $U(O)$ and $U(h)$ and that the wave velocity relative to the mean flow is always greater in magnitude than the classical value.

In the appendix the critical Froude number is investigated. The results are based upon the hypothesis that the flow in the laminar sublayer does not affect the critical Froude number extensively. Numerical results are plotted and a suggestion is made to take into account the effect of the stated hypothesis.

E. A. Trabant, USA

3144. Shuleĭkin, V. V., Hydrodynamic picture of the energy transmission of wind to waves (in Russian), *Dokiadi Akad. Nauk SSSR (N.S.)* **92,** 1, 41–44, Sept. 1953.

The problem of energy transmission from wind to two-dimensional water waves, formerly studied by Motzfeld (1937) and Neumann (1948) (not mentioned in the Russian text) is now treated by author in a quite different manner. Starting with the Lagrangian equations, and assuming orbit circles of the water particles nonstationary in amplitude and frequency, he develops the complicated differential equations of the problem. After simplification by special assumptions he introduces Jeffreys' relation for the wind-pressure disturbance and gets an equation for the growth of wave amplitude. The results are very different from known ones.

W. Wuest, Germany

3145. **Dmitriev, A. A., Waves on the surface of a viscous fluid which are generated by a pulsating source** (in Russian), *Izv. Akad. Nauk SSSR Ser. Geofiz.* **1953,** 335–345, 1953.

Author derives expressions for the surface waves due to a submerged source of intensity $-Q \cos \sigma t$. Inertial terms in the equations of motion are neglected (the resulting equations and boundary conditions are precisely those given in Lamb's "Hydrodynamics," 6th ed., Cambridge, 1932, §349, although the author credits them to an unavailable 1941 report of Sretenskiĭ). The equation of the free surface is

$$\eta = \mathrm{Re}\,\frac{Q \exp i\sigma t}{\pi}\,\frac{\sigma}{g}\int_0^\infty \frac{1 - 2i\chi^2}{4\epsilon^4\chi^3(\chi - (i + \chi^2)^{1/2}) - \chi^2] + i(\chi - \epsilon)} \times \exp(-h\chi)\cos\chi\xi\, d\xi$$

$$= Q\,\frac{\sigma}{g}\,(1 + 100\epsilon^4)^{1/2}\exp(-h\epsilon - 4\epsilon^3\xi) \times \cos(\sigma t - \epsilon\xi + 4\epsilon^3 h - \arctan 10\epsilon^2) + \ldots,$$

where $h(\nu/\sigma)^{1/2}$ is the depth of submersion of the source, $\xi(\nu/\sigma)^{1/2} = x$ is measured horizontally, and $\epsilon = \sigma^{3/2}\nu^{1/2}g$. The result is applied to a discussion of the damping of surface waves and of the formation of waves by a wave maker.

J. V. Wehausen, USA

Elasticity Theory

(See also Revs. 3086, 3182, 3190, 3218)

3146. **Laurson, P. G., and Cox, W. J., Mechanics of materials, 3rd ed.,** New York, John Wiley & Sons, Inc.; London, Chapman & Hall, Ltd., 1954, viii + 414 pp. $5.75.

This third edition of an excellent text on strength of materials is an improvement over the earlier editions through rewriting much of the subject matter, including many new illustrations, adding a series of new problems, shifting emphases to the more important material, and rearranging the presentation in a more logical and conformal order for present-day demands. The book is, indeed, timely, well written, and comprehensible.

The book is divided into 21 chapters, the first 13 of which are suggested as the basis for a typical course in strength of materials. From the remaining chapters, one may study various selected topics of relative importance.

Specifically, the first 13 chapters cover stress and deformation, mechanical properties of materials, stresses due to axial loads, shear and bending moments of beams, stresses in beams, deflections of beams, and thin-column theory. The later chapters deal with combined stresses, elastic energy theory, continuous beams, beams of two materials, eccentrically loaded connections, and, lastly, problems. Comprehensive appendixes and tables conclude the text.

The principal criticisms are that a glossary of terms has been omitted and at times the treatment is uneven. Furthermore, a few mechanical flaws were noted, such as the answer to problem 10-23 which is off by a factor of two; however, this is to be expected in any newly published book. G. B. White, USA

3147. **Sternberg, E., On Saint-Venant's principle,** *Quart. appl. Math.* **11,** 4, 393–402, Jan. 1954.

Ever since its first general statement by Boussinesq in 1885, proof of Saint Venant's principle has been the main outstanding problem of classical elasticity theory. While several asserted proofs have been published, they will not bear searching, and, in an important paper, von Mises [*Bull. Amer. math. Soc.* **51,** 555–562, 1945] shows that all the usual statements of the principle are either trivial, inconsistent, or untrue. Arguing from examples, von Mises conjectured a new formulation. It is essentially this formulation which the author states precisely and proves rigorously.

The main idea in the formulation is to consider as $\epsilon \to 0$ a family of solutions corresponding to prescribed surface loads limited to portions of the bounding surface lying within spheres of radius ϵ about a finite number of points. At a fixed point in the interior of the body, the stress, strain, and displacement (hereafter called "the elastic effects") are then calculated to the lowest order in ϵ. (It is important to notice that this concept of order, expressed by the symbol 0, is not related to the term "order of magnitude" as it is usually employed by engineers.) The point is, then, to see whether the elastic effects are of a higher order in ϵ for the case when the surface loads are equipollent to zero than when they are not.

The author's results are as follows: (a) When the resultant force is not zero, the elastic effects are $0(\epsilon^2)$ or smaller. (b) When the resultant force is zero, the effects are $0(\epsilon^3)$ or smaller. (c) When the load satisfies $\int x_i F_j d\sigma = 0$, the effects are $0(\epsilon^4)$ or smaller. (In this condition x_i is any rectangular coordinate, F_j any component of surface force, $d\sigma$ the element of surface area; this condition implies, but is not implied by, equipollence to zero.) (d) Loads equipollent to zero produce effects $0(\epsilon^3)$ or smaller. (Hence it does *not* follow that equilibrated loads always produce effects of smaller order than nonequilibrated ones, but it does follow that loads satisfying $\int x_i F_j d\sigma = 0$ produce effects which are of smaller order than those in *typical* cases when the applied moments are not zero.) (e) When the applied tractions are parallel and in astatic equilibrium, the effects are $0(\epsilon^4)$ or smaller. (f) When the loads are parallel, equipollent to zero, and not parallel to a tangent plane, then the effects are $0(\epsilon^4)$ or smaller.

The proof uses Betti's integration formulas and series expansion in powers of curvilinear coordinates on the surface of the body. The above statements refer to a finite body and to distributed loads. The author indicates their extension to the case of concentrated loads. The method of proof is essentially the same, finite sums replacing integrals, but all resulting orders of magnitude are lowered by two. In all cases, precise conditions of regularity on the body and on the loads are stated.

The author has shown that, in terms of this formulation, the idea of the usual Saint Venant principle cannot hold in general and the true facts do not justify the confidence which engineers often place in the principle. However, the author ends with the remark that his result by no means precludes the possibility of stronger Saint Venant theorems for special classes of bodies, such as thin plates or long prisms. C. Truesdell, USA

3148. **Schumann, W., Different formulations of Saint-Venant's principle** (in French), *C. R. Acad. Sci. Paris* **238,** 9, 988–992, Mar. 1954.

3149. **Filonenko-Borodich, M. M., Some generalizations of the Lamé problem for an elastic parallelepiped** (in Russian), *Prikl. Mat. Math.* **17,** 4, 465–469, July-Aug. 1953.

Author solved the state of stresses for an elastic parallelepiped in two previous articles [AMR **4,** Rev. 4094; **5,** Rev. 2569] using rectangular coordinates. Now he uses cylindrical coordinates and expresses in terms of them the components of the stress tensor equations, for the basic tensor satisfying conditions of equilibrium and boundary conditions, also for the complementary tensor for state of stress of a given body without surface stresses.

He shows general conditions for the stress functions and their form for a full or hollow cylinder and for sector of a hollow cylinder.
Z. Bažant, Czechoslovakia

3150. Goodier, J. N., and Hsu, C. S., Transmission of tension from a bar to a plate, *J. appl. Mech.* **21,** 2, 147–150, June 1954.

See AMR **7,** Rev. 1735.

3151. Dyson, J., and Hirst, W., The true contact area between solids, *Proc. phys. Soc. Lond. (B)* **67,** part 4, 412B, 309–312, Apr. 1954.

A new method for observing the points of real contact between two solid surfaces is described. A metallized glass surface is pressed into contact with the specimen, the glass surface being deformed locally at the points of contact. The opposite side of the metallized surface is examined through the glass by phase contrast microscopy, the deformations showing bright on a dark background. Deformations of a few Ångstroms in depth are detectable if their lateral extension is above the resolving limit of the microscope. Nominally flat, ground, polished, and lapped specimens of silver steel have been examined. With each specimen, true contact was made within regions the sizes and distribution of which were determined by the general undulations of the surface and by the magnitude of the applied load. The differences lay in the distribution of the local contact areas within the general regions. With the polished specimen, true contact was made over almost the whole of the general region, but with the ground specimen it was confined to a few isolated areas along the grinding ridges. True contact with the lapped specimens was made at a very great number of areas, each a few microns in linear dimension. From authors' summary

3152. Fichera, G., Condition for compatibility of the principle problem of elastostatics (in Italian), *Cons. naz. Ricer.* no. 379, 4 pp., 1953 = *R. C. Accad. Lincei* (8) **14,** 3, 397–400, Mar. 1953.

Author proves that, when it is required that displacements and stresses in an elastic, isotropic, and homogeneous body, clamped along part of its boundary, be represented by continuous functions, the body and surface forces which act on the free boundary cannot be fixed arbitrarily. The latter must fulfill a *quantitative* condition of integral type. The boundary problem being clarified, author observes that, from a physical point of view, the vectors f (body forces) and g (surface forces) may be fixed arbitrarily, as they are balanced by the reactions in the clamped part, but that *qualitative* characteristics only for f and g are not sufficient to secure a unique solution of the question. The demonstration, of a strictly mathematical character, results from four previous theorems which author deduces successively with respect to vectorial functions. A. M. Guzmán, Argentina

3153. Mitoff, S. P., and Pask, J. A., Thermal strains during firing of a ceramic body, *J. Amer. ceram. Soc.* **37,** 4, 168–172, Apr. 1954.

Factors determining the tendency of ceramic ware to crack during firing are said to be the temperature differences in the piece, thermal expansion, fracture strain, and shape. Each factor, except shape, is likely to change as firing progresses because of temperature dependence and/or changes in the material. Methods of measuring the changes of each factor during firing are demonstrated. By relating the factors, a curve indicating the tendency to crack at any time during firing is obtained. Authors suggest the use of such an approach for adjusting firing schedules in ceramic production. W. H. Duckworth, USA

Experimental Stress Analysis

(See also Revs. 3141, 3190, 3441)

3154. Schlumpf, U., On a type of stressing of railway rails not previously considered (in German), *Schweiz. Bauztg.* **72,** 1, 6–9, Jan. 1954.

Stresses in rail were measured during passage of locomotive. These showed longitudinal tension on bottom of rail head of approximately 3000 psi. It was concluded that this was produced by local vertical deformation of rail web. Mathematical analysis of problem was made by considering concentrated load resting on infinitely long beam (rail head) which in turn is fastened to upper edge of semi-infinite plate (rail web). An approximate analysis of this problem gave good agreement with the afore-mentioned measured stress. Author concludes that this stress could be reduced by using large-radius fillets at the juncture of rail head and web. G. W. Housner, USA

3155. Frocht, M. M., Guernsey, R., Jr., and Landsberg, D., Photoelasticity—a precision instrument of stress analysis, *Proc. Soc. exp. Stress Anal.* **11,** 1, 105–114, 1953.

Paper provides a concise and cogent insight into the attainment of precision and accuracy in the photoelastic measurement of stress concentrations in two dimensions. The requirements necessary to achieve these goals are outlined and several recommended procedures are more fully discussed, including improvements in the evaluation of the maximum and the average fringe orders. To demonstrate the accuracy of the techniques described, factors of stress concentration measured photoelastically for a tension bar with a central circular hole are compared with the theoretical solution by Howland. Also, stress-concentration factors obtained photoelastically are compared with the theoretical solutions of Neuber and Ling for a tension bar with semicircular grooves. There is a discussion of the paper by A. J. Durelli. W. Shelson, Canada

3156. Frocht, M. M., and Guernsey, R., Jr., A special investigation to develop a general method for three-dimensional photoelastic stress analysis, *NACA Rep.* 1148, 17 pp., 1953.

Supersedes article reviewed in AMR **6,** Rev. 2475.

3157. Schlechte, F. R., and Rosecrans, R., Experimental stress analysis of stiffened cylinders with cutouts. Pure torsions, *NACA TN* 3039, 41 pp., Nov. 1953.

Torsion tests were made on a cylindrical semimonocoque shell of circular cross section consisting of a 24S-T aluminum-alloy skin 0.051 in. thick, 36 external $^3/_4 \times {}^3/_4 \times {}^3/_{32}$-in. angle stringers, and 8 equally spaced Z-section rings of $^1/_8$-in. sheet. The rings were 2 in. deep with 1-in. flanges. The cylinder was first tested without a cutout, and then with a rectangular cutout which was successively enlarged through six sizes varying from 30° to 130° in circumference and from 1 to 2 bays in length. Strain measurements were made with resistance-type wire strain gages near the cutout on the stringers, the skin, and the rings for each size of cutout. Stresses computed from measured strains are presented in tables. B. L. Wilson, USA

3158. Layland, C. L., Rao, A. R. S., and Ramsdale, H. A., Experimental investigation of torsion in stranded mining wire ropes, *Instn. mech. Engrs. Proc. (B)* **1B,** 8, 323–336, 1952–1953.

Modulus of rigidity is primarily dependent upon construction (number of wires and strands), varies somewhat with type of lay and lubrication, and is rather independent of load and diameter. An approximation may be had by dividing the modulus of rigidity of steel by the total number of wires and multiplying by

the cosine of the helix angle. This gives good results except when more than 75 wires are used, in which event friction apparently leads to higher values.

Considerable data are provided for angular deflection in laying and unlaying direction, rotation due to tension, and extension due to rotation. C. M. Tyler, Jr., USA

3159. Czechowicz, J., A report on an x-ray investigation of the work of wood joints (in English), *Bull. Acad. Polonaise Sci. Cl.* IV, **1**, 3, 129–133, 1953.

Paper constitutes a special presentation of a small fragment of a more extensive research work carried out by the author on steel bolts as connectors in timber structures (in print). The joints investigated worked in compression and consisted basically of three wooden elements connected by a steel bolt of diameter d, provided with nuts and washers. The sum of thicknesses of the outside members $a + a$ was equal to the thickness of the center member c. The load was applied axially and was parallel to the grain of the wood. The ratio $c{:}d$ varied from 1.2 to 7.0. The application of x rays makes it possible to obtain a picture of destruction with all its vital features intact, whereas a section made through the joint cannot be effected without partial destruction of the most revealing areas. A detailed interpretation of 5 photographs of x-ray plates reproduced in the test has been included.

The character of destruction in joints made up of comparatively thin members ($c : d \leqslant 2$) is distinctly different from that in joints where the members are thick ($3 \leqslant c : d \leqslant 7$). In joints with comparatively thick members, the character of destruction is distinctly different when nuts and washers are used. The pattern of destruction of joints by bolts with nuts and washers can be roughly compared to that of a beam with both ends fixed; joints by bolts only, to that of a simple supported beam. The degree of compactness of the wood measured as the ratio of specific gravity of the wood in the areas of destruction to that of wood outside those areas was found to be between 1.5 and 2.1, the average ratio being 1.85. This value was not found to depend on the $c : d$ ratio. From author's summary

Rods, Beams, Shafts, Springs, Cables, etc.

(See also Revs. 3135, 3138, 3140, 3141, 3146, 3150, 3154, 3158, 3182, 3204)

3160. Lee, E. H., Plastic flow in a rectangularly notched bar subjected to tension, *J. appl. Mech.* **21,** 2, 140–146, June 1954.

See AMR **7,** Rev. 1470.

3161. Benscoter, S. U., A theory of torsion bending for multicell beams, *J. appl. Mech.* **21,** 1, 25–34, Mar. 1954.

See AMR **7,** Rev. 1045.

3162. Hill, H. V., Analysis and design of beams under given end restraints, *Civ. Engng., Lond.* **49,** 573, 257–259, Mar. 1954.

3163. Burgess, E. G., Jr., Minimization of gear-train inertia, *Trans. ASME* **76,** 3, 493–496, Apr. 1954.

In the design of a system consisting of a motor driving an inertial load through gearing, it is often necessary that the acceleration of the load be a maximum. The gear ratios giving a maximum acceleration are determined here either for a specified over-all train ratio or for the condition where the over-all ratio must be found. Charts, which embody certain simplifying assumptions, are provided for selecting the optimum number of gear ratios and the ratios of the individual meshes corresponding to maximum load acceleration. From author's summary

Plates, Disks, Shells, Membranes

(See also Revs. 3131, 3132, 3133, 3134, 3146, 3150, 3157, 3176, 3181, 3183)

3164. Yu, Y.-Y., Bending of isotropic thin plates by concentrated edge couples and forces, *J. appl. Mech.* **21,** 2, 129–139, June 1954.

See AMR **7,** Rev. 1063.

3165. Shaw, F. S., and Perrone, N., A numerical solution for the nonlinear deflection of membranes, *J. appl. Mech.* **21,** 2, 117–128, June 1954.

See AMR **7,** Rev. 1750.

3166. Boscher, J., Application of electric networks for the calculation of deformation of elastic plates (in French), *C. R. Acad. Sci. Paris* **238,** 11, 1189–1192, Mar. 1954.

3167. Burrows, W. R., Michel, R., and Rankin, A. W., A wall-thickness formula for high-pressure, high-temperature piping, *Trans. ASME* **76,** 3, 427–444, Apr. 1954.

See AMR **6,** Rev. 2199.

3168. Reismann, H., Bending of circular and ring-shaped plates on an elastic foundation, *J. appl. Mech.* **21,** 1, 45–51, Mar. 1954.

See AMR **7,** Rev. 1753.

3169. Zerna, W., Calculation of translation shells (in German), *Öst. Ing.-Arch.* **7,** 3, 181–187, 1953.

Basic equations for the calculation of the membrane stresses, the state of deformation, and the boundary stress-concentration effect in translation shells. H. Neuber, Germany

Editor's Note: Translation shell is the surface generated by moving a plane curve along a second plane curve to which it is perpendicular in such a manner that the plane of the moving curve remains parallel to its initial position.

3170. Horvay, G., and Clausen, I. M., Jr., Stresses and deformation of flanged shells, *J. appl. Mech.* **21,** 2, 109–116, June 1954.

See AMR **7,** Rev. 1057.

3171. Kempner, J., Postbuckling behavior of axially compressed circular cylindrical shells, *J. aero. Sci.* **21,** 5, 329–335, May 1954.

The postbuckling characteristics of an axially compressed thin-walled circular cylindrical shell loaded either by dead weights or by a rigid testing machine are determined. It is shown that, for either loading condition, the minimum applied stress in the postbucking region is $0.182(Et/R)$ and that the region of stable equilibrium corresponding to loading by the rigid testing machine includes and extends beyond that obtained with dead-weights loading. The work here described is a continuation of work done earlier by von Kármán and Tsien, by Michielsen, and by Leggett and Jones. From author's summary by G. V. R. Rao, USA

3172. Junger, M. C., Dynamic behavior of reinforced cylindrical shells in a vacuum and in a fluid, *J. appl. Mech.* **21,** 1, 35–41, Mar. 1954.

See AMR **7,** Rev. 1722.

3173. Chilingarishvili, G. I., The calculation of linings for high-head tunnels under internal pressure (in Russian), *Gidrotekh. Stroit.* **22**, 7, 27–30, July 1953.

The correct thickness of concrete linings for such tunnels may be calculated from an analytical formula, attributed to B. G. Galerkin (1929), treating an elastic cylindrical shell in an infinite elastic medium. Author presents a family of curves illustrating this formula and facilitating its use for practical problems.

The main features illustrated by the curves are: (1) If the elastic resistance of the concrete is greater than that of the surrounding medium, the maximum stress in the lining decreases with increasing thickness; (2) in the reverse case, the maximum stress increases with increasing thickness; (3) if the internal pressure is less than the maximum permissible stress, a suitable thickness for the lining can always be found; and (4) in the reverse case, a solution is sometimes not possible. A. H. Armstrong, England

3174. Das, S. C., Stress concentrations around a small spherical or spheroidal inclusion on the axis of a circular cylinder in torsion, *J. appl. Mech.* **21**, 1, 83–87, Mar. 1954.

See AMR **7**, Rev. 1034.

3175. Somervaille, I. J., Balancing a rotating disc. Simple graphical construction, *Engineering* **177**, 4595, 241–242, Feb. 1954.

Buckling Problems

(See also Revs. 3192, 3195, 3201)

3176. Peters, R. W., Buckling of long square tubes in combined compression and torsion and comparison with flat-plate buckling theories, *NACA TN* 3184, 15 pp., May 1954.

Paper presents very fine experimental results on the buckling of square tubes in combined compression and torsion. Interesting evidence is provided on the correct method for allowing for plasticity, on the true shape of the interaction curve, and on the insensitiveness of the final buckling to the mode of loading.
W. S. Hemp, England

3177. Krieg, K. H., Influence of creep of concrete on the buckling strength of reinforced-concrete columns (in German), *Beton u. Stahlbeton.* **49**, 2, 45–47, Feb. 1954.

Author gives approximate analysis of buckling load of column whose axis has slight initial curvature and considers effect of creep and nonlinear stress-strain relationship of concrete. Method is based on Engesser-von Kármán theory and linear relationship between elastic and creep deformations, which had been basis of previous methods using effective modulus of elasticity.

While results show in a qualitative way the importance of creep on the buckling load of imperfect columns, method ignores important effect of redistribution of stress from concrete to steel as creep proceeds. Moreover, author makes no mention of the limiting condition of straight columns when Euler buckling load decreases similarly with time because of creep.
G. G. Meyerhof, Canada

3178. Dutheil, J.; discussion by Massonnet, C., The theory of instability through disturbance of equilibrium (in French), *Publ. int. Assn. Bridge struct. Engng.*, 199–210, 1953; Fourth Congr., Cambridge and London, Aug. 25–Sept. 5, 1952.

Instability problems have to be regarded from two points of view: that of concordance with test results, and that of safety. The expression of the deflection of a member in compression is given as a function of the compression stress n; this is a sufficient hypothesis to solve all problems concerning the buckling of compressed bars and the lateral buckling of bent beams and is in good agreement with the results of tests.

The conception of a rational safety, established by taking into account the same degree of imperfection, the effects of which, however, are variable with the slenderness, is explained. The condition of homogeneity of that safety is established. The harmony and coherence of the solutions given for the principal problems are discussed. From author's summary

3179. Stüssi, F., On the theory of buckling in the plastic region (in German), *Publ. int. Assn. Bridge struct. Engng.*, 211–215, 1953; Fourth Congr., Cambridge and London, Aug. 25–Sept. 5, 1952.

In the case of a compressed bar, it is necessary to distinguish in principle between the problem of stability *per se* and the stress problem of the second order (initial deflections of finite size, lateral loading). It is possible to make allowances for unavoidable discrepancies from the ideal theoretical case either by using an appropriate factor of safety or by the introduction of a conventional initial deflection; the method chosen is not of great importance.

Buckling tests on "Peraluman" bars are referred to; since this material has a large zone between the limit of proportionality and that of yielding, these tests give a good idea of the plastic region of buckling. The Shanley theory (1947) [AMR **1**, Rev. 72] which restates in principle the first Engesser theory, agrees well with the test results, while the theory of Engesser-Kármán gives too high values for the buckling stresses.

The theoretical and experimental values for the buckling stresses do not agree, in their order of magnitude, with M. Dutheil's theory; this theory can, therefore, only be applied to materials whose stress-strain diagram possesses particular characteristics (pronounced plastic limit, very short zone between limit of proportionality and plastic region, e.g., structural steel) in order to lead to satisfactory results. From author's summary

3180. Feodos'ev, V. I., On the stability of a spherical shell under the action of an external uniformly distributed pressure (in Russian), *Prikl. Mat. Mekh.* **18**, 1, 35–42, Jan.–Feb. 1954. (English translation by M. D. Friedman is on file with Scientific Translation Division, Library of Congress.)

Paper is a further contribution to the intriguing and as yet incompletely understood problem of the elastic stability of a thin spherical shell under external pressure. The analysis is based upon Galerkin's method. It is shown that there are forms of equilibrium, involving large displacements over a relatively small region, that can exist for zero external pressures (and even some degree of internal pressure). This phenomenon is familiar through the behavior of a rubber ball that is not well inflated. Although the detailed results are of interest, they appear to have been foreshadowed to some extent, at least, by Friedrichs [Th. von Kármán Anniversary Volume, Cal. Inst. Tech., Pasadena, Calif., 1941, 258–272]. Moreover, in reviewer's opinion, it seems likely that further understanding of the problem will be obtained only through the elegant approach made by Friedrichs (loc. cit.). H. G. Hopkins, USA

3181. Ashwell, D. G., A characteristic type of instability in the large deflexions of elastic plates. III. Curved rectangular plates in axial compression, *Proc. roy. Soc. Lond.* (*A*) **222**, 1148, 44–59, Feb. 1954.

In an earlier paper [AMR **6**, Rev. 1205], author treated instability of initially curved rectangular plate subjected to bending moment perpendicular to axis of curvature. This paper extends analysis to another case where moments are applied on

the straight edges and compression on the initially curved edges.

Interesting observation is given upon the dependence of the axially symmetric buckling load in a long thin-walled circular tube upon the boundary condition at tube ends. Author predicts the buckling load for his case, which is equivalent to unrestrained edges, to be half the usual value when the edges are simply supported. M. L. Williams, USA

3182. **Worthington, P. M., The elastic stability of straight I-beams subjected to complex loads,** *Proc. Instn. civ. Engrs.*, part 1, **3,** 1, 46–65, Jan. 1954.

Paper describes a method of checking whether a long straight member of I-section, subjected to any load system, is stable. Only beams within the elastic range are treated. The method is to resolve the problem into a number of simpler problems, analyze each of them separately, and then superpose the results to give an approximate answer to the original case. The theory of superposition of the simple cases is discussed and some general approximate formulas are obtained.

An appendix is given which may be useful in the design office. In it are tabulated the results of many simple cases, together with the appropriate formulas.

From author's summary by J. W. Cohen, Holland

3183. **Micks, W. R., A method of estimating the compressive strength of optimum sheet-stiffener panels for arbitrary material properties, skin thickness, and stiffener shapes,** *J. aero. Sci.* 20, 10, 705–715, Oct. 1953.

A method is developed for estimating the strength properties of sheet-stiffener panels which approaches the condition of optimum design; i.e., the long-column buckling stress being the same as the local buckling stress of the stiffener web, etc. This is done by means of a shape factor k_3, which defines the bending efficiency of the basic stiffener combination. Variation of the factor k_3 with basic stiffener shapes is analyzed in detail. In applying this method to panel design, only material properties required are those that can be derived from a compression stress-strain diagram for the material. The synthesized results based on this method would also be useful in the evaluation of weight penalties associated with nonoptimum design, and in reduction of amount of actual testing work that is normally carried during a strength investigation of panels. C. C. Wan, USA

3184. **Massonnet, Ch., Experimental investigations regarding the resistance to buckling of the web plates of solid-web girders** (in French), *Publ. int. Assn. Bridge struct. Engng.*, 539–555, 1953; Fourth Congr., Cambridge and London, Aug. 25–Sept. 5, 1952.

After briefly referring to the theoretical solutions of the problem of the buckling of plates subjected to plane bending and shearing stressing, author describes his tests made on a transversely loaded girder of 13-m span and 1 m high with very thin web plates; the tests were made within the carrying capacity and up to failure of the girder.

During testing within the carrying capacity, the critical buckling load of each panel of the web was measured according to the Southwell method. During the tests to failure, the transverse stresses and deformations of the panels were determined, as well as the residual stresses and deformations that were present after again reducing the loads in the steps with increasing load. The tests show that buckling of webs is a progressive phenomenon much less dangerous than buckling of bars. The girder behaves elastically far beyond the theoretical critical load, and its final load is a multiple of the latter.

The author therefore concludes by suggesting that the factors of safety adopted should be smaller than those used at present.

From author's English summary

Joints and Joining Methods

(See also Revs. 3159, 3210, 3233)

3185. **Stoy, W., and Loehr, H., Influence of use of slender bolts and thin washers on load-carrying capacity of GEKA connectors in timber joints** (in German), *Holz als Roh- und Werkstoff* 12, 64–67, Feb. 1954.

Matched three-member compression joints of green fir were assembled with two pairs of spiked ring connectors, two concentric bolts, and two pairs of round washers placed in line with the direction of load application. For the first test series, the sizes of both bolts and washers varied. For the second test series, two pairs of smaller spiked ring-connectors were embedded concentrically within the larger size connectors in the same planes of the joint members.

The use of slightly smaller washers than required according to German standards is satisfactory, provided the bolt size is not decreased. If sizes of bolts and washers are reduced, the design load is to be decreased. Concentric insertion of small connectors within the larger connectors decreased the load-carrying capacity of the joint.

These findings are in agreement with results of similar tests performed with split-ring connectored joints tested in the United States. E. G. Stern, USA

3186. **Harris, L. A., Matthiesen, R. B., and Newmark, N. M., Low-temperature bend test properties of bead-on-plate welds,** *Welding J.* **32,** 12, 585s–599s, Dec. 1953.

Studies are reported on the low-temperature bend test properties of notched E6010 and E6016 bead-on-plate welds subjected to various treatments. The beads were deposited on steels which were selected to correspond to ASTM designations A7, A285C, and A242. The effects of low-temperature cooling rate embrittlement were investigated by testing welds which were water-quenched after welding. In addition, the effects of preheating and postheating were studied. Separate series of specimens were tested with the direction of the applied stress either parallel to or transverse to the direction of welding. The base of the notch was located so that the properties of the specimens could be investigated at the center of the weld metal, near the fusion line, or in the heat-affected zone. In order to compare the bend properties of the specimens notched to different depths, the results are interpreted in terms of the proportion of the maximum deflection of corresponding plain plate specimens. An investigation of the effects of the weld reinforcement on the bend properties and of the method of interpretation of the weld-bead bend test is contained in the appendix. From authors' summary

3187. **Wilson, W. J., Spot welding of aluminum, aluminum alloys and steel,** *Welding J.* **32,** 12, 1175–1180, Dec. 1953.

3188. **Riordan, J. M., Repair welding of ceramic-coated alloys,** *Welding J.* **32,** 12, 1160–1166, Dec. 1953.

Structures

(See also Revs. 3138, 3139, 3154, 3173, 3177, 3180, 3183, 3184, 3225, 3232, 3407)

3189. **Bažant, Z., Dictionary of structural mechanics [Slovník stavebné mechaniky a příbuznych oboru v pěti řečích],** Praha, Nakladatelství Československé Akad. Věd., 1953, 251 pp. 15 Kčs.

This is a dictionary of about 2000 important terms in the field

of structural mechanics, giving translations from Czech into Russian, English, French, and German. Terms are also cross-indexed alphabetically in the four latter languages, making it most useful to workers in this field throughout the world. Ed.

3190. Baker, J. F., The steel skeleton. Vol. I: Elastic behaviour and design, New York, Cambridge Univ. Press, 1954, xii + 206 pp. $8.50.

Twenty-five years ago the Department of Scientific and Industrial Research of Great Britain formed a Steel Structures Research Committee which for seven years investigated the behavior of steel building frames and their components by extensive theoretical analysis, laboratory research, and full-scale observations on large buildings in London. The results of these studies were published in three detailed reports in 1931, 1934, and 1936, together with recommendations for design. In spite of the importance of this investigation, of which much was carried out by the author as Technical Officer to the Committee, this work is not sufficiently well known, even in Great Britain. It is therefore timely that the author has published under one cover the main results of this research and some subsequent investigations on the behavior of steel-framed buildings.

After reviewing different building codes governing the design of steel frames, author describes in detail the observations made on an experimental frame and a number of existing steel-framed buildings of various stiffnesses with riveted and bolted beam-column connections. Loading tests were made on the bare frame, on the frame with floors laid before and after encasing the columns and, in one case, after the enclosing walls were built. The results of these observations, which even today are probably the most extensive ever undertaken on multistory buildings, showed that the behavior of an actual building approximated more closely that of a rigid frame than that of a structure with simply supported beams. In addition, it was found that the presence of floors and encasement reduced side sway to a small amount, while at the same time the stresses in beams were decreased and the column stresses were either decreased or increased depending on the rigidity of the connections.

The stress analysis of frames with semirigid beam-column connections is treated by extending the slope-deflection and moment-distribution methods on the basis of the moment-angle relationships of the connections. These relationships were obtained from a detailed laboratory investigation of the behavior of typical connections of various rigidities to derive lower limit curves for the end restraint, and it is shown how the results were used to develop a rational method of designing beams. The corresponding procedure of designing columns was based on perfectly rigid connections and necessitated a study of the critical loading conditions in frames to determine the worst axial loads and bending moments under single and double curvature in any length of a continuous column.

As mentioned in the last chapter of the book, the new method of designing frames with semirigid beam-column connections unfortunately did not gain support from the engineering profession, mainly because the suggested procedure did not lead to any significant economy of steel compared with standard and much simpler methods ignoring the rigidity of connections. While the weight of steel in beams is reduced by up to 20%, the steel in columns is increased by a similar amount. The reviewer believes that some of this lack of economy in the columns is due to many simplifying and to some extent over-conservative assumptions leading to excessive column stresses. Thus the Committee's design curves for columns are not only based on the worst arrangement of column layout and loading, but for slender columns the considerable reduction and even reversal of the end moments as buckling is approached have been ignored. Nevertheless, it is doubtful whether a design based on elastic conditions is the most rational procedure, because the real factor of safety of structures can only be determined from an estimate of the collapse load based on elastoplastic behavior. This approach of limit design will be discussed by the author in a companion volume to be called "Plastic behaviour and design."

G. G. Meyerhof, Canada

3191. Fries, W., Trusses and rigid frames [Fachwerk und Rahmenwerk], Berlin, Springer-Verlag, 1953, x + 378 pp. DM 42.

In this volume author develops a treatment of theory of structures as applied to trusses and rigid frames, based on one single principle of virtual work, along the same line as did Prof. Grüning in his "Statik des ebenen Tragwerkes," 1925. Author uses for computation of stresses two methods: the old one, classical, developed mostly by Müller-Breslau in his "Statik der Baukonstruktionen"—method of forces; and the more recent method of deformation, due mostly to Ostenfield ("Die Deformations Methode," 1926) and Mann ("Theorie der Rahmenwerke," 1927).

The work contains rather few worked-out examples of computation and is not a book for easy understanding. It does present an important contribution to the field of theory of structures. Reviewer, however, is skeptical about usefulness of this book as a textbook on theory of structures. J. B. Gabrys, USA

3192. Paris, P. C., Limit design of columns, *J. aero. Sci.* **21,** 1, 43–49, Jan. 1954.

An extremely simple expression is derived for the relation between load and axial deformation of column in buckled state, involving plastic deformation in bending. Application to "limit design" is suggested. Expression is substantiated by tests. Agreement is highly satisfactory except for very short columns.

Phenomenon of sudden release of energy in early stage of buckling is named "plastic dynamic buckling" and is introduced as a new concept.

Reviewer remarks that similar phenomena are known in elastic range, for instance, with buckling of curved shells ("oil canning"), and he believes that just the "dynamic" character of this phenomenon may jeopardize application of the load-deflection curves presented on static problems.

H. F. Michielsen, USA

3193. Massonnet, Ch., Investigation of the design and reasonable stiffening of plate girders with special regard to warping (in French), *Ann. Inst. tech. Bât. Trav. publics* **6,** 71, 1061–1078, 1 fig., Nov. 1953.

In the introduction, author discusses the advantages of plate girders in comparison with truss girders and gives the theoretical formulas of Timoshenko and others for the warping of plate girders treated as rectangular plates whose length is equal to the spacing of the vertical stiffeners. Then he uses the equation $(\sigma_{cr}:\sigma_{c^0r})^2 + (\tau_{cr}:\tau_{c^0r})^2 = 1$, which expresses the relationship between the stresses σ_{cr} and τ_{cr}, corresponding to the warping under simultaneous bending and shear, and the stresses σ_{c^0r} and τ_{c^0r} corresponding to the case of pure bending or pure shear. The behavior of the plate after exceeding the critical load is different from the behavior of the compressed bar after exceeding the critical force. In the plate, membrane stresses occur which exert great stabilizing influence.

This problem is quite complex without enlisting the aid of experiments. Such experiments are made by author with a beam of following dimensions: span 13 m, height 1 m. This beam was divided by vertical stiffeners into 13 unequal panels.

The transverse deformations of the web as a function of the

critical load show them to be continuously increasing—hence it is very difficult to determine the moment at which the critical load is attained. Hence, Southwell's method is applied for the determination of the critical load for the compressed bar by measurement of the transverse deflections. However, this method may be applied only for small transverse deformations.

Author describes in detail the tests he made in Liège in 1948 and 1949. Beam was loaded by means of hydraulic jacks which may be included singly, by two, or by three. In this manner, 44 kinds of loading may be realized, which, by using the Southwell diagram, gives the 155 critical various loads for 13 panels of the beam. According to the assumed accuracy of the results (10%), 42 results are rejected. The results of experiment are illustrated by 7 diagrams, in coordinates σ_{cr} and τ_{cr}, which also show the results of theoretical calculations based on the formulas of Timoshenko, Nölke, and Inguchi. From these diagrams it follows that the critical stresses determined experimentally are higher than the theoretical ones, and that the dispersion of the results is considerable. In three cases the test was continued to the destruction of the beam.

The tests show that by warping of the plate girder, the sudden character of the phenomenon does not occur; therefore, warping considered from a point of view of safety has the same significance as bending or shear, and not buckling.

Author gives the graphs which make it possible to determine the factor of safety with regard to warping, the spacing of vertical stiffeners, and the thickness of a web. After concluding that the vertical stiffeners do not sufficiently protect the beam against warping, author discusses the problem of horizontal stiffeners. Graphs are given which make it possible to determine the optimum horizontal stiffeners. W. Wierzbicki, Poland

3194. Grinter, L. E., and Tsao, C. H., Joint translation by cantilever moment distribution, *Proc. Amer. Soc. civ. Engrs.* **79,** Separ. no. 298, 9 pp., Oct. 1953.

The moment distribution in continuous structures may be determined by the Hardy-Cross method. The problem is solved directly under the assumption of joint rotation. The incorporation of joint translation requires an indirect solution. The paper extends the Hardy-Cross method by modifying the degree of fixity of the members in the structure. This permits a direct solution of certain problems involving joint translation.

H. H. Dixon, USA

3195. Greisch, R., and Massonnet, Ch., Tables for quickly determining the web-plate thickness of a plate girder and the distance apart of the vertical stiffeners, taking into consideration the danger of buckling (in French), *Publ. int. Assn. Bridge struct. Engng.*, 299–308, 1953; Fourth Congr., Cambridge and London, Aug. 25–Sept. 5, 1952.

Authors give a table which allows the dimensions of the webs of plate girders to be quickly determined. The chief features of this table are:

(1) Direct reading, without any graphic construction being required.

(2) Manifold applications. The table considers simultaneously the normal stresses σ and the shear stresses τ in the web. It can be adopted for ST 37 and ST 52 in the elastic and plastic regions, and also if the web has a horizontal stiffening at half height, or at $^3/_4$ height.

The table allows the following three fundamental problems to be solved in a few seconds (a, b, and e being the width, height, and thickness of the web, respectively): (1) Determining the safety against buckling σ, when a, b, e, σ, and τ are given. (2) Determining the distance apart of the vertical stiffenings a, when b, e, σ, τ, and s are given. (3) Determining the web thickness e, when a, b, σ, τ, and s are given.

From authors' English summary

3196. Faber, O., Reinforced concrete, London, E. & F. N. Spon, Ltd., 1952, 232 pp. 30s.

The reputation of the author and his recognized competence to handle the fundamental aspects of his subject assure that this book will be approached with interest by many structural engineers. There are a number of rewards to be had by way of expressions of the author's personal philosophy of design, and especially a clear cost consciousness that most students and many teachers could profitably emulate. The number of disappointments are equally as great. The coverage is rather restricted. Specialized structures such as chimneys, silos, bunkers, shells, reservoirs, and piles are briefly and insufficiently treated to the complete exclusion of slabs, floor systems, retaining walls, and other common, less glamorous concrete structures. No mention is made of the considerable research and literature that France, Germany, and the United States have contributed to the title subject, and indeed, with the exception of two or three rather general references to British publications and isolated names, the author chooses to refer only to his personal work. His significant researches, however valuable, thereby suffer in impact on the reader through lack of comparison with similar studies having wider acceptance.

The first four chapters, on properties of concrete and component materials, are standard in content, but contain a number of wise observations on undesirable cracking, shrinkage, and plasticity. Chap. 5 is an elementary treatment of design of beams and slab elements. Chap. 6 lists values of beam moments for frequently met cases, but presupposes the reader to be well versed in principles of continuity. Chap. 7 discusses elementary aspects of beam shear and shear reinforcement. Chap. 8, on bond, is wholly inadequate and, being limited to plain bars, would not have much meaning for American engineers and others using deformed, high-bond bars. Columns and footings are covered briefly in chaps. 9 and 10. Special structures, mentioned above, are treated in chaps. 11 to 15 in a fashion, perhaps necessarily, which allows only a shallow understanding of the most general aspects of design and techniques of construction. Chaps. 16 and 17 briefly explain British Code specifications for precast and prestressed concrete. G. P. Fisher, USA

3197. Morice, P. B., and Little, G., Load distribution in prestressed concrete bridge systems, *Struct. Engr.* **32,** 3, 83–111, Mar. 1954.

Paper is divided into three parts. In the first one (14 pp.), the problem of load distribution in a bridge made of interconnected prestressed beams is stated and various methods which have been suggested for its solution are mentioned. Authors draw particular attention to the methods which replace the bridge by a continuous grillage of beams or an anisotropic plate, i.e., the method due to Guyon [*Ann. Ponts Chauss.*, 553–612, Sept.-Oct. 1946] and its generalization by this reviewer [*Inter. Assn. Bridge struc. Engng. Publ.* **10,** Zurich, 147–182, 1950]. The techniques of practical calculation using distribution coefficients are given in detail. The results of computational work of Guyon and Massonnet for no-torsion and torsion structures are given in the form of graphs and tables which may be used for practical design.

The second part of the paper (8 pp.) is devoted to a description of tests of three interconnected beam systems, two simply supported at the ends and one continuous over three supports. Prin-

cipal results of the tests are as follows: (1) The two simply supported grillages behaved as no-torsion grillages in good agreement with the Guyon theory; the continuous grillage showed good agreement with torsion calculations based upon the analysis of Massonnet.

(2) In the continuous specimen, the effects of transversal distribution are virtually eliminated by the simple central support and do not appear in the unloaded span.

(3) The required transverse prestress is that which will maintain the joints of the system up to the required working load of the grillage or for slight overload. The value of the working load will vary for different load eccentricities and the limiting condition must be determined for the maximum practical eccentricity.

The third part of the paper (7 pp.) contains three numerical examples devoted to a simply supported grillage, a continuous grillage, and a practical prestressed beam bridge, respectively. The last two examples include an analysis of the torsion effect.

Ch. Massonnet, Belgium

3198. Chunn, C. J., and Bell, F. M., Testing for construction and evaluation of airport pavements, *Proc. Amer. Soc. civ. Engrs.* **80,** Separ. no. 418, 22 pp., Mar. 1954.

3199. Carrack, D. H., and Robertson, D. G., The effects of jet aircraft on airfield pavements, and associated problems, *Proc. Instn. civ. Engrs.*, part II, **3,** 1, 1–30, Feb. 1954.

Paper describes the results of tests conducted with Meteor aircraft equipped with Derwent Mark 1 jet engine. Tests were conducted on both flexible and rigid types of pavements. Maximum values of jet-stream characteristics were in the order of 1500 fps for the velocity and 1200 F for the temperature. Maximum angle of inclination of engine to the horizontal was 12°.

The tests have not disclosed anything that has not been known from previous tests conducted since the end of World War II. Present-day designers are more interested in the effects that afterburning turbojets of tomorrow may produce on pavements. Maximum values for these jet streams may be expected to reach 8000 fps in velocity and 5000 F in temperature.

M. V. Smirnoff, USA

3200. Seltenhammer, L., Practical application of the *n*-free ultimate load method to the design of rectangular reinforced-concrete sections in bending (in German), *Beton u. Stahlbeton.* **48,** 5, 6; 110–116, 144–146, May, June 1953.

Purpose of this method is to base design of reinforced concrete on method which agrees with the real behavior to greater extent than orthodox design and insures increased economy. It is based on maximum strain reached at failure; for concrete, 3%; for steel, 8 to 10% (strength approx. 64,000 psi) and 20% (strength between 64,000 and 128,000 psi). Idealized shapes of stress-strain diagrams for steel and concrete are used, and simple formulas are derived for the design based on ultimate load. Maximum strain of concrete at failure is of little influence as long as it is between 2½ and 4%, though different shapes of the concrete stress-strain line affect the carrying capacity to a much greater extent. The stress-strain diagram for concrete has been assumed as a parabola, reaching 78.5% of cube strength at strain of 1.8%, then this maximum stress remaining up to strain of 2% and then gradually reduced to 75% of cube strength in parabolic curve between the strains 2 and 3%. Method is extended also to compressive reinforcement and includes calculation of load causing cracking, based on modulus of rupture of ⅛ of cube strength. This assumption is, in reviewer's view, too general for concretes of different strength.

Formulas derived appear satisfactory as long as concrete used corresponds to behavior assumed, but they will not agree with actual behavior if different types of concrete are used, e.g., high-strength brittle concrete of nearly straight line stress-strain curve and limited ultimate strain, or weak concrete of curved stress-strain line with large ultimate strain.

Suggestion of designing reinforced concrete for ultimate load condition and controlling the state of cracking is certainly sound, but formulas ought to be adjusted also for materials of other properties than those corresponding to assumed stress-strain curves, to insure that design is in all cases in good agreement with the actual behavior, which is the aim of the author.

P. W. Abeles, England

3201. Anderson, R. A., Johnson, A. E., Jr., and Wilder, T. W., III, Design data for multipost-stiffened wings in bending, *NACA TN* 3118, 31 pp., Jan. 1954.

Results of a computational program are presented which give numerical values of the stiffnesses required of the various components of a multipost-stiffened wing to achieve desired buckling-stress values under bending loads. Two arrangements of the posts are considered, upright posts and posts used as diagonals of a Warren truss. This work extends and summarizes the calculations presented in *NACA RM* L52K10a.

Procedures that might be used in evaluating these stiffness quantities for practical construction have been indicated. Results indicate that, over a wide range of structural parameters, the required stiffnesses can be achieved with structural members of practical size. Comparison of these results with those of a similar analysis of multipost-stiffened beams without stringers shows that, for the same post configuration, appreciably higher buckling stresses can be developed when small stringers are used in conjunction with posts.

From authors' summary by R. E. Heninger, USA

3202. Roberts, H. E., Design features of the XH-26 "Jet Jeep" helicopter, *Aero. Engng. Rev.* **13,** 1, 37–45, Jan. 1954.

Rheology (Plastic, Viscoplastic Flow)

(See also Revs. 3160, 3171, 3177, 3230, 3243, 3342)

3203. Weiss, H. J., and Prager, W., The bursting speed of a rotating plastic disc, *J. aero. Sci.* **21,** 3, 196–200, Mar. 1954.

Paper deals with the analysis of the stresses and permanent strains in a rotating disk having a central hole and of initially uniform thickness in a completely plastic state. The elastic parts of strain are neglected, and for the law of yielding the maximum shearing-stress theory of Tresca is postulated, based on a conventional tensile stress-strain curve of the nominal stress $s = f(\epsilon)$ for finite values of the tensile strain of conventional type ϵ. The analysis is based on the equilibrium condition of the true stresses σ_r, σ_θ in radial and tangential direction, assuming that in a thin disk the axial stress σ_z vanishes and utilizes the fact that the tangential stress σ_θ in a revolving disk is always a tensile stress and greater than the radial tensile stress σ_r, so that the true tangential stress behaves during the yielding of the disk as if it were the true stress in a tensile test.

Authors express the square of the angular velocity of the disk ω^2 in terms of a definite integral in whose integrant the quantities $f(\eta/\xi)$, ξ, η, and α appear, where $f(\eta/\xi)$ denotes the strain-hardening function in tension, $\xi = r_0/a_0$, $\eta = u/a_0$, $\alpha = b_0/a_0$ (a_0, b_0 initial values of inner and outer radius of disk, r_0 initial variable radius of a point, and u the radial displacement it under-

goes during the yielding). Two examples are considered in the paper by assuming that the strain-hardening function is a straight line and a logarithmic curve. In the first case, corresponding to the unusually steeply inclined slope of the straight line, authors assume the disk starts to flow in a stable manner and continues so with increasing ω, while in the second case, corresponding to a much gentler rising stress-strain curve, a bursting speed exists.

A. Nadai, USA

3204. **Hill, R., The plastic torsion of anisotropic bars,** *J. Mech. Phys. Solids* **2,** 2, 87–91, Jan. 1954.

Author treats the torsion problem in a prismatic bar of anisotropic, ductile material in the plastic state. The anisotropy is of the orthotropic type with one principal axis parallel to the axis of the bar and assumed to be the same in any section. The torque and mode of warping of the cross sections at the yield point of the fully plastic bar are calculated. Author denotes the components of shearing stress in the states of simple shear prevailing in each element of the bar by p and q in a point x, y. When the bar is in the fully plastic state they satisfy a yield condition of the form

$$f(p^2, q^2, x, y) = 0 \qquad [1]$$

in which only the squares of p and q appear by virtue of the orthotropic symmetry and the condition of equilibrium

$$\partial p/\partial x + \partial q/\partial y = 0 \qquad [2]$$

with the boundary condition

$$q\,dp = dy/dx \qquad [3]$$

The directions of the characteristic curves of [1] are given by

$$dp/(\partial f/\partial y) = -dq/(\partial f/\partial x) = dx/(\partial f/\partial q) = -dy/(\partial f/\partial p) \qquad [4]$$

In particular, when the anisotropy does not vary across the sections, $\partial f/\partial x = \partial f/\partial y = 0$ and $dp = dq = 0$, the characteristics are straight lines and along them the resultant shearing stress is uniform. The magnitude of it is obtained from [1] and [3]. In an isotropic bar [1] reduces to

$$p^2 + q^2 = k^2 = \text{const} \qquad [5]$$

Hill discusses the determination of the warping of originally plane sections and considers the particular type of anisotropy for which [1] is expressed by $p^2/p_0^2 + q^2/q_0^2 = 1$, p_0, q_0 being the shear yield stresses in the directions x, y. He considers elliptic and rectangular cross sections computing the torques.

A. Nadai, USA

3205. **Drucker, D. C., Coulomb friction, plasticity, and limit loads,** *J. appl. Mech.* **21,** 1, 71–74, Mar. 1954.

See AMR **7**, Rev. 1788.

3206. **Green, A. P., On the use of hodographs in problems of plane plastic strain,** *J. Mech. Phys. Solids* **2,** 2, 73–80, Jan. 1954.

Paper is a useful discussion of the hodograph defined by Prager in 1952 [AMR **6,** Rev. 3731]. Author discusses certain properties possessed by the hodograph in relation to the slip-line field. In particular, he gives a rapid method for assessing whether or not the rate of plastic work is everywhere positive throughout the field. Method involves merely observing the curvature of corresponding arcs of the two fields, although reviewer would point out that care must be taken in defining the positive direction of increasing arc length along corresponding α and β lines of the two fields.

Effect on hodograph of translation and rotation, and identity of slip-line field and hodograph occurring in problems having simple boundary conditions, are briefly discussed. Particular solution of problem of compression between partially rough dies in which slip lines meet dies at constant angle is described. It is demonstrated that, for very large die-width/material-thickness ratio, if it be assumed Prandtl's cycloid solution applies to both slip-line field *and* hodograph, Nadai's equations for velocity distribution are uniquely determined. Problems involving geometrical similarity are also considered, and it is shown that this condition is conveniently expressed as a relationship between hodograph and free surface.

J. M. Alexander, England

3207. **Benthem, J. P., Note on the general stress-strain relations of some ideal bodies showing the phenomena of creep and of relaxation,** *Nat. LuchtLab. Amsterdam Rap.* S.426, 9 pp., 1953.

Report deals with the general stress-strain relations of isotropic linear bodies. Linear bodies are defined as those whose stress-strain relations may be represented by models consisting of combinations of linear springs and dashpots. The Hookian solid, the compressible viscous liquid, the Kelvin solid, the Maxwell solid or liquid, and generalizations of these are drawn and discussed. Emphasis is placed on the necessity for infinite volume viscosity of the Maxwell type. Models of plastic and viscoplastic behavior are also depicted.

D. C. Drucker, USA

3208. **Kneser, H. O., Mechanical relaxation of simple systems** (in German), *Kolloid Z.* **134,** 1, 20–30, Dec. 1953.

This review article deals first with the elastic, viscous, and plastic behavior of substances in general and then specifically with simple relaxation phenomena. Three types of relaxation processes are described; temperature, pressure, and entropy relaxation. Experimental methods for studying these phenomena are reviewed. Results of measurements on gases and liquids, carried out by the author during the last two decades, are summarized, and the work by Dijkstra and others on relaxation measurements in solids is cited.

A. W. Cochardt, USA

3209. **Massonnet, Ch., Plastic collapse and shake-down tests on small rolled beams** (in French), *Publ. int. Assn. Bridge struc. Engng.* **13,** 239–282, 1953.

Author, in first chapter, deals with the fundamental notions of plastic deformations and the criterion of plastic collapse of a statically redundant structure. He shows that the increase in strength applies only to the case in which all the external loads increase proportionally.

In second chapter, details are given of experiments which were carried out to compare the theory of plastic collapse with practice. Author describes the equipment and method used for loading the test beams and measuring the plastic deformations. The tests show that the experimental loads are slightly higher than the theoretical values and that it is dangerous to apply the theory of plastic bending to statically indeterminate beams which are not adequately supported laterally.

Reviewer completely agrees with last paragraph of author's summary.

R. D. Teague, England

3210. **Green, A. P., The plastic yielding of metal junctions due to combined shear and pressure,** *J. Mech. Phys. Solids* **2,** 3, 197–211, Apr. 1954.

Paper examines both plane strain and plane stress conditions in junctions connecting two massive blocks of plastic-rigid material. Author differentiates between "strong junctions" with no relative sliding at the junction and "weak" junctions at which sliding occurs. Both wedge-shaped and parallel-sided junctions

are considered. Analysis, based on the mathematical theory of plasticity, enables the forces involved to be computed. Experimental confirmation of the suggested deformation modes is obtained in certain cases.

Reviewer believes this to be an interesting and important contribution to the theory of friction between unlubricated surfaces. J. F. W. Bishop, Scotland

3211. Rosenthal, D., and Kaufman, M., Load-temperature history of lattice strain in aluminum alloy, *J. Metals* **6,** 3, 377–380, Mar. 1954.

Back-reflection x-ray technique was used to evaluate the suitability of lattice strain as a parameter for an equation of state. Tensile tests of 61S aluminum alloy were performed at (1) room temperature, (2) −195 C, (3) room temperature after prestressing at −195 C, and (4) −195 C after prestressing at room temperature. Lattice strains in the bitemperature tests fall between the strains obtained in the isothermal tests, implying failure of the equation of state. In view of large scatter of data, reviewer agrees with authors that additional tests are warranted before definite conclusion is reached. L. Mordfin, USA

3212. Gifkins, R. C., Structural studies of the creep of lead, *J. Inst. Metals* **82,** 39–47, 3 plates, 1953–1954.

3213. Sorokin, O. V., and Sazanova, N. D., Relation between creep and relaxation of stresses in metals, Nat. Sci. Found. tr-152, Dec. 1953; *Doklady Akad. Nauk SSSR (N.S.)* **92,** 3, 565–568, Sept. 1953.

3214. Leaderman, H., Approximations in linear viscoelasticity theory: delta function approximations, *J. appl. Phys.* **25,** 3, 294–296, Mar. 1954.

Relationships between approximations recently proposed in connection with the linear viscoelastic behavior of noncrosslinked amorphous polymers are discussed.

From author's summary by M. Mooney, USA

Failure, Mechanics of Solid State

(See also Revs. 3211, 3234)

3215. Bailey, J. M., and Godfrey, D., Coefficient of friction and damage to contact area during the early stages of fretting. II—Steel, iron oxide, and glass combinations, *NACA TN* 3144, 26 pp., Apr. 1954.

Experiments were conducted to study the start of fretting and the cause of damage during the early stages (up to 490 cycles) of fretting of steel-steel combinations at a frequency of 5 cpm, an amplitude of 0.006 in., a load of 150 grams, in air with relative humidity of less than 10%. Pure iron, glass, and iron-oxide powder compacts were used in supplementary experiments. The results of microscopic observation of the contact area and measurements of coefficient of friction lead to these conclusions:

(1) Fretting starts with severe adhesion between surfaces. The adhesion varies with the material combination, as shown by the initial coefficient of friction, but is of primary importance because it precedes and initiates the other phenomena observed.

(2) In the early stages of fretting, several other wear phenomena in addition to adhesion occur. Their relative importance varies with the materials fretted, and they can occur simultaneously at different points within a contact area. They are: (a) Plowing by protruding transferred material (the plowing is more pronounced when adhesion is greater); (b) formation of debris (loose fragments): Oxide debris is not evident when large wear fragments are produced, whereas oxide debris (Fe_2O_3) is evident in a very few cycles if the wear fragments are small; (c) formation of films by compacting small particles into clearances in the contact area: The formation occurs readily if one of the surfaces is hard. These films can plow the opposing metal surface.

From authors' summary by E. I. Shobert, USA

3216. Godfrey, D., and Bailey, J. M., Coefficient of friction and damage to contact area during the early stages of fretting I—Glass, copper, or steel against copper, *NACA TN* 3011, 23 pp., Sept. 1953.

Experiments were conducted to measure the coefficient of friction μ and to determine the damage to the contact area during early stages of fretting of copper at a frequency of 5 cpm. Specimen combinations of copper against glass, copper against copper, and copper against steel, as well as various copper-oxide films and powder compacts, were used.

The results lead to the conclusion that fretting of copper starts with the same mechanical damage that occurs during unidirectional sliding. Fretting of copper against glass, copper against copper, and copper against steel starts with adhesion and metal transfer (galling), with accompanying high μ values (< 1.0) the same as those obtained during unidirectional sliding. After the initial high values of μ, a reduction in μ was observed, associated with reduced plowing and an increasing concentration of debris in and around the contact area. After approximately 100 cycles of fretting, μ reached a constant value (0.5–0.6), approximately the same as that obtained with compacts of either cuprous or cupric oxide.

The presence of preformed cuprous- or cupric-oxide films on copper does not delay the occurrence of fretting but only lowers the initial coefficient of friction.

From authors' summary by E. I. Shobert, USA

3217. Marco, S. M., and Starkey, W. L., A concept of fatigue damage, *Trans. ASME* **76,** 4, 627–632, May 1954

A valuable contribution to the study of fatigue damage has been made by the authors. Numerous tests to failure were performed on 76S-T 61 aluminum alloy and SAE 4340 steel alloy. Care was taken to insure identical physical properties for the respective materials. The specimens were subjected to different stress levels to obtain failure. Specimens were subjected to low-high stress levels and other specimens to high-low stress levels.

The test results indicate that the type of fracture is a function of the stress level. Low stress levels will fail at a predominant weak point in the material, whereas high stress levels will fail at many weak points (flaws) at the same time. Using $\Sigma (n_i/N_i)$ as the criterion of failure, it was observed that the specimens, which were subjected to a high stress level and then to a lower stress level, would fail at less than unity. For specimens tested in the reversed order of stress levels, $\Sigma (n_i/N_i)$ was observed to be greater than unity. From the results of their test, authors propose that sum of cycle ratios for the various stress levels be zero when no cyclic-stress history exists, and be unity when the specimen has broken into two pieces. V. P. Zimnoch, USA

3218. Tidball, R. A., and Shrut, M. M., Thermal-shocking austenitic stainless steels with molten metals, *Trans. ASME* **76,** 4, 639–643, May 1954.

Low thermal resistance of interface between pipe wall and molten sodium-potassium alloy used as heat-transfer medium results in temperature changes of inner pipe wall equal to that of

liquid metal, causing rapid stress fluctuations in excess of yield point of container material. Temperature stresses are calculated on basis of linear temperature gradient through pipe-wall thickness. Test pieces were 3-ft sections of 8-in. schedule 40 AISI-type 347 stainless-steel pipes containing three circumferential equidistant butt welds. Very ingenious test setup, interesting in itself, permitted application of thermal shocks at 4 cycles per hour by cooling from 850 F at 100 F per sec.

Temperature profiles recorded for 8 seconds, duration at 0.5, 0.75, 1.0, 1.25, 2.0, 2.5, and 3.0 seconds and every second after that were used to determine stress history at inner wall. Maximum stress occurs at 1.5 sec and is 92,000 psi and decreases to 27,000 psi at 8 seconds.

Test results showed that cracks several microinches long left after welding increase to twice their length in consequence of 2500 shocks, but thermal shocks do not produce new cracks.

R. Week, England

3219. Harris, L. A., Matthiesen, R. B., and Newmark, N. M., Fatigue properties of weld metal, *Welding J.* **32,** 9, 441s–453s, Sept. 1953.

3220. Stüssi, F., Fatigue strength of aluminum alloys (in German), *Publ. int. Assn. Bridge struct. Engng.* **13,** 357–366, 1953.

From an analysis of fatigue test results obtained with a strong aluminum alloy, a relation between the fatigue strength and the mean cyc'e stress could be established, presuming only knowledge of the static tensile strength and the Wöhler curve (i.e., the *S-N* curve for zero mean stress).

The equation for the Wöhler curve given by author is identical with that suggested by Weibull [**AMR 6,** Rev. 1259].

N. H. Polakowski, USA

Material Test Techniques

(See also Rev. 3235)

3221. Thorsen, W. J., An improved strain gage for precise force measurement in single fibers, *Text. Res. J.* **24,** 5, 407–413, May 1954.

An unbonded resistance wire strain gage is described that is sensitive to small forces, has high precision and accuracy, and is simple to construct. The low inertia and high stability of this gage make it especially suitable for the precise measurement of stress relaxation in single textile fibers over periods lasting from milliseconds to as long as 2 months or more. The output of the gage is sufficient for direct coupling to recording potentiometers.

From author's summary

3222. Puzak, P. P., and Pellini, W. S., Evaluation of notch-bend specimens, *Welding J.* **33,** 4, 187s–192s, Apr. 1954.

The energy, fracture appearance, and ductility (lateral contraction) transition characteristics of Charpy V, Charpy keyhole, and Schnadt Coheracic specimens were evaluated with respect to relative significance and practicability for correlation to service performance of welded structures. It is concluded that the Charpy V energy-transition curve provides the most significant and practical method of correlation based on the use of small notch-bend specimens.

The limitations of the use of Charpy V transition data for different classes of structural steels (rimmed and semikilled vs. fully killed) are discussed. A criterion of energy which is determined to be proper for a given type of steel may not necessarily apply to a different type. It is demonstrated that Charpy V specimens *per se* show differences in fracture behavior which depend on the type of steel. From authors' summary

3223. Kaiser, J., Conclusions deduced from measurement of noises appearing in tension tests of metallic materials (in German), *Arch. Eisenhüttenw.* **24,** 1/2, 43–45, Jan./Feb. 1953.

3224. Anonymous, Comparative tests of soniscopes for ultrasonic testing of concrete, *Wwys. Exp. Sta. Misc. Pap.* no. 6–48, 29 pp., Sept. 1953.

Consideration of the results of all of the tests described in the paper leads to the following conclusions: Reproducibility of results obtained with normal uncracked concrete, using various operators and soniscopes, is good to within 2% for massive structures; with care, it may be kept to within 1%. Wider variation may be expected for short path lengths of the order of 1 ft or less. Variation of results obtained with different soniscopes in tests of cracked concrete is high, being of the order of 20%. The extent to which this variation is influenced by the judgment of the operator, by minor variations in the location of transducers, and by surface conditions is not clear. The effect on the reproducibility of results of various operators and equipment of the types tested is not a major factor for uncracked concrete. Different crews can retest structures without need for comparison of crews in assessing results if the crews are reasonably well trained and equipment is functioning properly. Variations in consecutive velocity readings of less than 2% are probably not significant. Variations of greater than 5% probably are significant. Intermediate variations require careful consideration before results may be reliably interpreted. From summary

Mechanical Properties of Specific Materials

(See also Revs. 3153, 3159, 3185, 3187, 3211, 3212, 3213, 3218, 3219, 3220, 3221, 3443)

3225. Himsworth, F. R., The variability of concrete and its effect on mix design, *Proc. Instn. civ. Engrs.* **3,** 2, part 1, 163–200, Mar. 1954.

Statistical analysis of a considerable number of tests leads author to conclude that the standard deviation s of the compressive strength of concrete is approximately independent of the mean strength $\bar{x}$ as generally inferred. Author therefore proposes that minimum strength be taken as mean strength less a fixed percentage of s in lieu of usual rule, which takes minimum strength as a fixed percentage of $\bar{x}$, thus penalizing higher-strength concretes.

Author also examines causes of variation in concrete strength and is able to show that less than 10% of the variation may be ascribed to the cement itself. He concludes that adequate control over concrete strength may be obtained by regulating workability of the mix at the mixer. J. E. Goldberg, USA

3226. Warren, C., Determination of properties of air voids in concrete, *Highway Research Board Bull.* 70, 1–10, 1953.

Report describes a statistical method of estimating the size, specific surface, and distribution of voids in concrete. A section is polished, the voids filled with fluorescent material, and the section photographed under ultraviolet light. Good agreement was found between the air content found by this statistical method and as determined by the pressure method. Some interesting data are given on the effects of various percentages of air-entrainment and various cement factors of the void characteristics. I. A. Benjamin, USA

3227. Mardulier, F. J., Entrained air benefits lightweight-aggregate concrete, *Civ. Engng., N. Y.* **24,** 1, 56–59, Jan. 1954.

3228. Van Der Beck, R. R., and Everhart, J. O., Weight loss and oxidation behavior of structural bodies during firing, *J. Amer. ceram. Soc.* **36,** 11, 383–388, Nov. 1953.

Paper concerns the oxidation behavior of a group of clay materials that had previously been studied for dimensional changes during firing. Authors show how the rate of firing can be regulated to take care of the moisture content; the oxidation of organic carbon, hydrocarbons, and carbonates; and the oxidation of sulphurous materials such as pyrites and sulphates. The recommendations as to firing procedures are based on tests of 20 materials, including clays, shales, and mixtures of clays and shales.

E. A. Davis, USA

3229. Koble, R. A., Jones, P. R., and Koehler, W. A., Blending and conveying of ceramic raw materials by fluidization, *Bull. Amer. ceram. Soc.* **32,** 11, 367–372, Nov. 1953.

3230. Sage, A. M., Steels for steam power plant, *Instn. mech. Engrs. Proc.* (*A*) **167,** 4, 414–424, Jan.-Dec. 1953.

A review of the work carried out for the Steels for High Temperature Committee of the British Electrical and Allied Industries Research Association between 1930 and 1952. Ed.

3231. Enzian, G. H., Behavior of carbon and low-alloy steels between −20 and +650°F, *Welding J.* **32,** 12, 605s–618s, Dec. 1953.

3232. Bannister, J. L., Cold drawn prestressing wire, *Struct. Engr.* **31,** 8, 203–218, Aug. 1953.

3233. Benthem, J. P., and Kruithof, R., Investigation on the strength of 24S-T Alclad riveted and bolted lap joints at rapidly applied loads, *Nat. LuchtLab. Amsterdam Rap.* S145, 18 pp., July 1953.

Tests were carried out to determine the failing strength of riveted and bolted single lap joints under rapidly applied loads, representative of gust loads or landing-impact loads on aircraft.

The load was applied to the specimens within a short time, which ranged from 0.91 sec up to 1.5 sec, while load-versus-time diagrams were recorded. The failing load of the riveted specimens was less than their static strength; for the bolted specimens, no decrease of strength was apparent.

From authors' summary

3234. Bennett, J. A., and Weinberg, J. G., Fatigue notch sensitivity of some aluminum alloys, *J. Res. nat. Bur. Stands.* **52,** 5, 235–245, May 1954.

The notch sensitivity in fatigue was determined for 24S-T4, 61S-T6, and 75S-T6 aluminum alloys. Specimens having theoretical stress-concentration factors of 1.0, 1.4, and 1.8 were used, and the fatigue-strength reduction factor was based on the number of cycles required to initiate the fatigue crack. The values of notch sensitivity for 61S-T6 in the small radius specimens and for 24S-T4 were close to unity, whereas that for 75S-T6 was much lower. The data also provide information on the dispersion of fatigue results for the different alloys and the portion of the total life required for a fatigue crack to grow to fracture. From authors' summary

3235. Holt, Marshall, Results of edge-compression tests on stiffened flat-sheet panels of alclad and nonclad 14S-T6, 24S-T6, 24S-T3, and 75S-T6 aluminum alloys, *NACA TN* 3023, 18 pp., Apr. 1954.

This investigation was made to augment data previously obtained on the compressive strengths of stiffened flat-sheet panels to include the range where ultimate strengths approach the compressive yield strengths of the materials. The ultimate strengths of the panels tested varied from 93.3 to 118.0% of the compressive yield strengths of the materials from which they were constructed. The ultimate strengths of these panels appear to be limited by the strengths of the rivets. Higher ultimate strengths might have resulted from the use of larger or stronger rivets or a smaller rivet spacing. From author's summary

3236. Reed, E. L., Stability of refractories in liquid metals, *J. Amer. ceram. Soc.* **37,** 3, 146–153, Mar. 1954.

Present technological developments are making more extensive use of liquid metals as heat-transfer agents. Their stable and relatively noncorrosive character makes them especially adaptable for high-temperature applications. The compatibility of various liquid metals with refractories has been investigated in the past over a temperature range up to several hundred degrees centigrade. To extend this information to much higher temperatures, corrosion experiments were carried out utilizing liquid sodium, tin, and bismuth. Tests were conducted in the range 800 to 1500 C using molybdenum, tantalum, tungsten, graphite, alumina, zirconia, and other materials. The experimental apparatus and procedures employed in conducting both static and dynamic tests are described and significant results are summarized.

From author's summary

3237. Marshall, I., and Thompson, A. B., The cold drawing of high polymers, *Proc. roy. Soc. Lond.* (*A*) **221,** 1147, 541–557, Feb. 1954.

Like many other polymers, amorphous polyethyleneteraphthalate cold-draws in the shoulders of a neck when stretched at room temperature. The draw ratio across the shoulders is not a constant for the polymer, but is found to depend on the temperature and speed of stretching and on the initial specimen cross section and birefringence. A local temperature rise is also observed in the shoulders. Isothermal load-extension curves have therefore been measured from 20 to 140 C, and from them an adiabatic load-extension curve has been calculated. This has a negative slope range which appears to be unstable. An alternative process of extension at constant tension in a shoulder, coupled with exchanges of heat along the specimen by conduction, appears to be possible at a lower tension than that needed for pure adiabatic extension. For this second process, the length of the shoulder, the tension at which it operates, and the draw ratio across it, can be calculated from the simple adiabatic curve and are found to agree with experimental data within a factor of two. This theory is then used to discuss cold drawing in some other polymers.

From authors' summary

3238. Sprague, G. R., Corrigan, J. J., and Sereque, A. F., The versatility of cellular rubber in engineering, ASME Ann. Meet., New York, Dec. 1953. Pap. 53—A-127, 7 pp.

3239. Kloot, N. H., A survey of the mechanical properties of some fiber building boards, *Austral. J. sci. Res.* **5,** 1, 18–35, Mar. 1954.

Mechanical tests have been conducted on 20 makes of hardboard and 10 makes of insulating board. A number of properties have been determined for the material in the normal dry condition and some on specimens soaked in water for 24 hours.

From author's summary

3240. Davidson, A. N., The relaxation shrinkage of woven wool fabrics during soaking in water and Hoffman pressing, *J. Text. Inst. Trans.* **45,** 4, T323–T347, Apr. 1954.

3241. **Brown, H. M., Correlation of yarn strength with fiber strength measured at different gage lengths,** *Textile Res. J.* 24, 3, 251–260, Mar. 1954.

The fiber strengths of 105 cottons measured with the Clemson Flat Bundle Tester at 0-, 2-, 4-, 6-, and 8-mm gage length were correlated with the strength of yarns made from the same cottons.

The correlation between single-end yarn strength and flat-bundle fiber strength was higher for all of the longer gage lengths than for so-called zero-gage length, being highest for 2 and 4 mm. For these gage lengths, the coefficients of correlation ranged from 5% to 27% higher than for zero lengths for the several types and numbers of yarn.

The correlations for the skein strength favored the longer gage lengths even more than in the single end breaks, the coefficients ranging from 3% to 49% higher for 2 to 4-mm gage lengths than for zero length. The results indicate that the increase in correlation with greater gage length, up to 4 mm, is higher the finer the yarns, and also higher for combed yarns than for carded yarns.

From the tests, it seems that the "equivalent gripping distance" on individual fibers in yarn breaks must be approximately 3 mm and that measuring the fiber strength at the short lengths used in the Pressley test will incorrectly rank certain cottons in relation to their merit in yarns. From author's summary

Mechanics of Forming and Cutting

3242. **Rögnitz, H., edited by, Hütte, Handbook for operation and production engineers. 4th rev. and enlarged ed., Vol. I. Manufacture. Vol. II. Operation [Hütte. Taschenbuch für Betriebsingenieure (Betriebshütte). Bd. I. Fertigung. Bd. II. Betrieb],** Berlin, Wilhelm Ernst & Sohn, 1954. xxviii + 939 pp., 2046 figs., 382 tables; xxiii + 727 pp., 1075 figs., 304 tables. DM 69.50; DM 54.

3243. **Shaw, M. C., and Finnie, I., The shear stress in metal cutting,** Ann. Meet. ASME, New York, Dec. 1953. Paper 53—A-158, 17 pp.

The several factors that could influence the flow stress in cutting are considered, and it is found that the presence of a normal stress on the shear plane, the temperature on the shear plane, and the higher rates of strain in cutting are of negligible importance. The interrelationship between temperature and strain rate is treated theoretically and the two effects are found to tend to cancel. It is shown experimentally that a material cut does not behave as an ideal plastic, but that the modulus of strain hardening is essentially the same at the high rates of strain encountered in cutting as in other materials tests carried out at low rates of strain.

From authors' summary by L. V. Colwell, USA

3244. **Thunell, B., Motion and cutting conditions of gang saws** (in Swedish), *Sven. TräforskInst. Medd.* 41B, 15 pp., 1953.

The motion conditions of gang saws are examined and the displacement, speed, and acceleration of the mobile frame are given for three different types of frame guides. The mass forces are studied and are combined with the mean shear forces to determine the pressure against the mobile frame guides.

The relative movement of the teeth and the log is determinative for the cutting and the sawdust formation. These movements are calculated and the results are applied to determine the influence of the overhang, the feed, etc., on the tooth incision, the instantaneous chip thickness, and the sawdust volume. The necessary clearance angle of the teeth is also calculated.

From author's summary by V. K. Kokkonen, Sweden

3245. **Babcock, R. S., Recent developments in powder cutting processes,** *Welding J.* 32, 10, 986–991, Oct. 1953.

3246. **Ford, H., and Wistreich, J. G., Problems of the control of dimension, shape, and finish in the rolling of sheet and strip and in the drawing of wire,** *J. Inst. Metals* 82, 281–290, 1953–1954.

The general principles of control are examined in relation to the dimensions, shape, and finish of sheet, strip, and wire. The main sources of variations are discussed, and reference is made generally to the problem of hot rolling as it affects both strip and rod.

The control of dimensions in sheet and strip involves the measurement of thickness along the length and across the width. The causes of errors are described, and the methods for manual and automatic control are detailed.

There is a fundamental difference between wire drawing and rolling in the control of dimensions, because the die bore is of fixed dimensions; this is discussed with regard to tolerances on gage and allowable wear. Difficulties of continuous measurement and problems of ovality are discussed.

The control of shape is shown to depend upon the same factors in wire-drawing as in rolling, but the factors are of different degrees of importance.

Of the three properties, surface finish is the least amenable to measurement and control, and the dependence of finish on the forming process is as yet little understood. Roll finish, die polish, and lubricants are discussed in so far as they affect smoothness and luster. From authors' summary

3247. **Bland, D. R., A note on the theory of rolling with tensions,** *Instn. mech. Engrs. Proc.* (*A*) **167,** 4, 371–372, Jan.-Dec. 1953.

In this note is suggested a modification to overcome the difficulty met in the application of Bland and Ford's simplified theory of strip rolling to passes where heavy back tensions are applied. An equation for the roll force is evolved and compared with those of Orowan and of Bland and Ford. Experimental and calculated values of roll force given show an accuracy to within 10%. From author's summary

3248. **Holman, A. T., Part I; Lawrie, W. B., Part II; The control and observation of dust at portable abrasive wheels and pneumatic chisels,** *Chartered mech. Engr.* 1, 3, 119–122, Mar. 1954.

3249. **Asbridge, G. H., Design of precision grinding machines,** *Instn. mech. Engrs. Proc.* (*A*) **167,** 4, 402–407, Jan.-Dec. 1953.

Hydraulics; Cavitation; Transport

(See also Revs. 3117, 3143, 3173)

3250. **Hadekel, R., Hydraulic systems and equipment,** New York, Cambridge University Press, 1954, viii + 224 pp. $3.75.

In a few pages of the introductory chapter, author outlines the necessary elements of fluid mechanics; he devotes the rest of his book to specific discussions of design problems, how they are solved, and the components of different hydraulic systems.

Much of the material of this book appeared first as a series of articles in *Mach. Design*, April to August 1953. Ed.

3251. Watkins, R. D., and Brebner, A., Model-scale relations for open channels with non-uniform flow, *Proc. Instn. civ. Engrs.* **3,** 1, part 3, 183–215, Apr. 1954.

A theory is derived to provide scale adjustments in order to obtain similitude in model studies of open-channel flow where boundary shear and inertia effects both occur. The theory is applied to cases of uniform and nonuniform flow and to distorted models. An analysis is made of a ski-jump spillway channel.

A. L. Jorissen, USA

3252. Kindsvater, C. E., and Randolph, R. R., Jr., Hydraulic model studies of Martin Dam draft tubes, *Proc. Amer. Soc. civ. Engrs.* **80,** Separ. no. 382, 17 pp., Jan. 1954.

3253. Hellström, B., and Rundgren, L., Model tests on Ölands Södra Grund lighthouse, *Trans. roy. Inst. Technol. Stockholm.* no. 76, 66 pp., 1954; *Instn. of Hydraulics Bull.* 39.

Authors describe quite completely both the procedures and results of above-titled model study. Purpose of investigation was to determine detailed information on the effects of wave motion on the lighthouse and on the underlying ground. The various tests included erosion about the base, general characteristics of wave pile-up on the lighthouse, dynamic pressures on the vertical walls, uplift pressure on the underslab, and total horizontal force.

From the prototype lighthouse there were obtained wave pressures on the vertical caisson from the direction of incident waves and uplift pressures on the underslab. Very good agreement was obtained between model and prototype.

H. G. Farmer, Jr., USA

3254. Fidman, B. A., Results of measurement of turbulence in uniform flow with sudden increase of depth (in Russian), *Izv. Akad. Nauk SSSR Otd. tekh. Nauk* no. 11, 1630–1644, 1 plate, Nov. 1953.

Experimental method described in following review is applied to a wider field of Reynolds number. Comparison is made of flow for $Re = 2550$ and $Re = 17{,}400$. Also, the effect of a corrugated bottom is compared with that of a flat bottom. Paper is of interest in relation to study of flow in canals and hydroelectric installations.

A. Gordon-Foster, England

3255. Fidman, B. A., Field of velocities of a water current at a sudden increase of depth (in Russian), *Izv. Akad. Nauk SSSR Otd. tekh. Nauk* no. 4, 512–522, Apr. 1953.

Paper presents a hydrodynamical study of velocities and induced turbulence in near laminar flow, as a result of step. Experiment was made by statistical analysis of cinematographical shots of brilliantly illuminated droplets of emulsion of density 1. Region of induced turbulence was 13 times height of step.

A. Gordon-Foster, England

3256. Ivanova, L. S., Apparent mass of a liquid filling an open rectangular container (in Russian), *Prikl. Mat. Mekh.* **17,** 4, 491–495, July-Aug. 1953.

Apparent mass is usually computed for a volume of solid body moving in incompressible liquid. Author extends that idea to a liquid with free surface in an open vessel. Analysis is confined to a weightless, incompressible, nonviscous liquid in a rectangular container which suddenly starts to move horizontally. Integration of the impulses on a cross section results in an elliptical integral of the first kind. Relationship is established between the apparent mass and the ratio depth/length of container. Two extreme cases of the container length are shown. Article is of interest for theoretical hydrodynamics.

S. Kolupaila, USA

3257. Talobre, J., The present state of underground penstock technique, *Wwys. Exp. Sta. Transl.* no. 53–9, 35 pp., 1953.

Author discusses basic problems associated with design and construction of underground penstocks, illustrating his remarks with references to a number of European projects. Most of the penstocks described have an inner steel lining separated from rock by a concrete lining, but mention is made of all concrete-lined penstocks as well as unlined penstocks. Essentially, the criteria governing the design of linings are: (1) sufficient strength to resist internal water pressure without leakage, (2) provision for relief of, or adequate resistance to uplift pressure due to ground water.

Dealing with (1), author quotes the Maurice Lévy rule that an all-concrete lining remains watertight so long as the combined effect of all forces acting on it is to put the lining in compression. Thus various methods of prestressing the concrete lining have been developed, including the use of circumferential wires and pressure grouting. The sealing effect of grouting also takes care of (2), thus obviating the necessity of incorporating drainage galleries which adversely affect the stress distribution in the rock and lining.

There is a brief discussion of the relevant rock properties, namely, compressive strength and stress-strain relationship. Laboratory and field techniques for measuring these properties are described. Some practical problems are reviewed: excavation, choice of lining, connection to powerhouse, use of drainage galleries. The paper concludes with an account of a number of penstock failures in Europe. This section of the paper is particularly interesting because design and construction procedure in this field are necessarily dependent on empirical data.

Author predicts that much progress will be made in the use of underground penstocks as a result of current advances in the techniques of rock mechanics and prestressing.

L. Schenker, USA

3258. Prince, C., Theoretical analysis of weirs of the caisson type (in French), *Schweiz. Bauztg.* **71,** 27, 391–396, July 1953.

Work concerns the upper leaf of gates of the European type known as "à crochet," undoubtedly those of Birsfelden described in title source, p. 363, June 20, 1953. The shape of the structure seen from the side is a ⌐ (vertical member upstream) which caps the lower leaf. The horizontal member is a caisson beam supported at each end; the vertical member is a skin plate welded to vertical girders, rigidly fixed to the caisson, and supported at their lower end by a roller running on the lower leaf. Author gives theoretical and practical indications on the computation of: (1) Characteristic elements of this whole complex piece: principal axes of inertia, center of torsion, etc. (2) Moments transmitted by vertical girders to the caisson, hence exact stress conditions and statically indeterminate reactions at the rollers.

Methods utilized are those of F. Stüssi ["Long bars, with caisson section and thin walls" (in French), *Mémoires A.I.P.C.* 11, 1951; "Statics of structures" (in German), Basel, 1946, Birkhaüser, editor; "Shear center and torsion" (in French), ibid., 12, 1952].

R. Lemoine, France

3259. Lindgren, E. R., Note on the flow of liquids in tubes, *Appl. sci. Res.* (*A*) **4,** 4, 313–316, 6 figs., 1954.

A recent paper has shown that generally accepted ideas concerning the transition between laminar and turbulent fluid motion in smooth pipes are very probably erroneous. The present article is intended to serve as an illustration of this reference, with some observations reported there examined from other points of view.

Particularly, the concept of the laminar sublayer as a special part of the turbulent boundary layer is called in question.

From author's summary

3260. **Addison, H., Instruction and research in hydraulic laboratories,** *Instn. mech. Engrs. Proc.* (*B*) **1B**, 9, 401–419, 1952–1953.

3261. **Dunne, B., and Cassen, B., Some phenomena associated with supersonic liquid jets,** *J. appl. Phys.* **25**, 5, 569–572, May 1954.

Some liquid jets were produced in air by means of a spring-loaded injector. At high jet velocities, another type of breakup seems to occur besides the classical Rayleigh surface-tension breakup and the sinuous aerodynamic breakup. Rotationally symmetric waves are formed, and appear to "break" analogous to wind-produced waves on a body of water. The rate of cavitation of jets in water was studied for several jet velocities above the speed of sound in air. From authors' summary

3262. **Chien, N., Water jet pumps for sediment circulation,** *Univ. Calif. Inst. Engng. Res.* (M.R.D. Sediment Ser. No. 1), 19 pp., Oct. 1952.

3263. **Vasil'ev, V. M., Flow of a concrete mix through a pipeline** (in Russian), *Gidrotekh. Stroit.* **22**, 7, 25–26, July 1953.

Incompressible Flow: Laminar; Viscous

(See also Revs. 3086, 3091, 3099, 3145, 3259, 3285, 3309, 3315, 3349, 3370)

3264. **Den Hartog, J. P., Recent technical manifestations of von Kármán's wake,** *Proc. nat. Acad. Sci. Wash.* **40**, 3, 155–157, Mar. 1954.

Author states Strouhal formula, which gives the frequency of the Kármán street shed by a circular cylinder and which is usually considered to be valid only at Reynolds numbers below critical, is also valid for Reynolds number of interest in large smokestacks where the Reynolds number is as high as 7×10^6. Comprehensive experimental investigation of lateral force due to vortex shedding as a function of Reynolds number, amplitude, and frequency of oscillation is considered required for complete understanding of self-excited oscillation of various cylindrical obstacles. Examples of two recent cases of smokestack oscillation and remedial action taken are discussed. P. A. Libby, USA

3265. **Byrd, P. F., An integral equation occurring in the theory of a slender quasi-axisymmetrical body,** *J. aero. Sci.* **21**, 5, p. 351, May 1954.

3266. **Escande, L., Transient régime around a circular cylinder** (in French), *C. R. Acad. Sci. Paris* **238**, 11, 1177–1179, Mar. 1954.

3267. **Schlichting, H., Results and problems in cascade investigations** (in German), *Z. Flugwiss.* **1**, 5, 109–122, Oct. 1953.

The report summarizes the investigations made in recent years at the Institute of Fluid Mechanics at the Technical University of Braunschweig, regarding flow through cascades. With the theoretical calculations of a nonviscous incompressible flow through plane cascades of airfoils, it was possible to derive simple solutions for the so-called "indirect problem" and "direct problem." The viscous flow was also calculated for the two-dimensional cascade in accordance with boundary-layer theory, thus giving a theoretical estimate of the loss coefficients. The change of the loss coefficients with the cascade-parameters solidity and angle of stagger is shown for a systematic variety of cascades. The amount of computational work for the individual case is greatly reduced by using an extensive tabulation of certain "influence functions" to such an extent that systematic theoretical research of cascade problems is brought into the range of practical approach. A convenient method for computation, based on the Prandtl-Glauert law, is given for the case of two-dimensional flow through cascades at high subsonic velocities.

The theoretical results are compared with systematic experimental data on a two-dimensional cascade. Special attention was given to the realization of two-dimensional flow by means of boundary-layer slots and suction. The measurements are in good agreement with the theoretical results, pressure distributions as well as loss coefficients. Extensive measurements have also been carried out on axial-flow cascades with various hub ratios. All the cascades tested had untwisted blades. The cascades were tested with a purely axial inflow and a considerable swirl at the outflow. A comparison of the measurements with those of the two-dimensional cascade with the same airfoils indicates that, for axial cascades, the effect of "radial divergence," i.e., change of solidity along the radius, on the pressure distribution over the blades and on the loss coefficients is small. Finally, some experimental results are given for cascades with gaps.

From author's summary by Y. K. Jan, Holland

3268. **Nekrasov, A. I., Determination of two-dimensional potential motion of an incompressible fluid, based on given values of the magnitude of its velocity** (in Russian), *Prikl. Mat. Mekh.* **17**, 4, 483–484, July-Aug. 1953.

A simple solution of the problem is presented for this case: When $\varphi(x, y)$ is the velocity potential of the investigated motion, $q(x, y)$ is the given magnitude of its velocity, then $\Delta\varphi = \partial^2\varphi/\partial x^2 + \partial^2\varphi/\partial y^2 = 0$ and $[(\partial\varphi/\partial x)^2 + (\partial\varphi/\partial y)^2]^{1/2} = q(x, y)$. It follows that

$$\partial^2\varphi^2/\partial x^2 + \partial^2\varphi^2/\partial y^2 = 2\,\varphi\Delta\varphi + 2\,[(\partial\varphi/\partial x)^2 + (\partial\varphi/\partial y)^2] = 2q^2\,(x, y)$$

If $\psi(x, y)$ is the stream function, then

$$\varphi(x, y) + i\psi(x, y) = w(z)$$

where $w(z)$ is the complex velocity potential. If δ is the angle of the velocity sector with respect to the x-axis, then

$$-(dw/dz) = qe^{-i\delta};\ \log(-dz/dw) = -\log q + i\delta = f(z)$$

Then the solution of the problem is

$$w = -\int e^{-f(z)}\,dz + \text{const.}$$

T. Riabokin, USA

3269. **Lindgren, E. R., Some aspects of the change between laminar and turbulent flow of liquids in cylindrical tubes,** *Ark. Fysik* **7**, 23, 293–308, Apr. 1953.

Because of the theoretical prediction of stability for axisymmetric Poiseuille flows by Pretsch [*ZAMM* **21**, 1941] and the many discrepancies in the transition experiments in pipes, the problem is re-examined by performing experiments similar to those of Schiller [*ZAMM* **1**, **14**, 1921, 1934] and Binnie [*Proc. phys. Soc.* **57**, 1945]. Large disturbances were introduced at the pipe entrance in order that a minimum critical Reynolds number

could be found. Schiller found that at sufficient distances downstream of the entrance, transition occurred instantaneously at the critical Reynolds number, whereas Binnie always found a continuous transition between laminar and turbulent flow. Binnie felt, however, that in the main Schiller's work was verified by his.

Visual observations and pressure measurements in the present paper led to the following results which for the most part substantiate Binnie: (1) The transition in smooth circular pipe proceeds continuously (at least up to $Re = 3300$); (2) the pressure discontinuity (resistance increase) at certain Reynolds numbers does not mean an instantaneous onset of turbulence; (3) the vorticity of flows with high entrance disturbances in smooth circular pipes decreases with distance traveled; (4) the Reynolds number by no means is a crucial variable that alone determines whether the flow shall be laminar or turbulent; (5) classical experiments in determing the lower "critical" Reynolds numbers have been misinterpreted and there does not exist a critical Reynolds number of the value 2300 (as determined by Schiller); (6) turbulent "flashes" were encountered.

On the basis of these results (in particular since no instantaneous transition was encountered), present author reaches a conclusion different from those of Schiller and Binnie, namely, that "laminar flow in smooth cylindrical tubes has never given any experimental evidence of instability." Author believes further verification of this unusual result is necessary.

Reviewer found paper somewhat difficult to read because esoteric expressions are used in key descriptions so that precise meaning was not always clear. No distinct differentiation was made between instability and transition, as is commonly done. Reviewer would like to point out that the apparent paradox of stability theory in predicting stability for axisymmetric Poiseuille flow was treated by Tatsumi [AMR **6**, Rev. 1653], who examined the flow in pipes before it became fully developed and found that this inlet flow was unstable so that transition might well precede the formation of the Poiseuille profile. No mention is made in paper under consideration as to whether the profiles always became fully developed. With regard to the matter of instantaneous transition, reviewer would like to point out that the type of measurements and visual observations made yield essentially time-averaged or macroscopic results. Recent research by Evvard, Tucker, and Burgess [*NACA TN* 3100, 1954] in supersonic streams indicates that the transition point fluctuates in a random manner. Application of statistical methods shows that such fluctuations, if studied macroscopically, would indicate a continuous transition region. S. Ostrach, USA

Compressible Flow, Gas Dynamics

(See also Revs. 3261, 3264, 3286, 3289, 3311, 3353)

3270. Shapiro, A. H., and Kline, S. J., On the thickness of normal shock waves in a perfect gas, *J. appl. Mech.* **21,** 2, 185–192, June 1954.

See AMR **7,** Rev. 1178.

3271. Blackman, V. H., and Weimer, D. K., The reflection of shock waves from a blunt wedge, *Phys. Rev.* **94,** 3, 508–510, May 1954.

The pseudostationary field resulting from the head- on reflection of a shock wave at a corner of angle $(\pi - \delta)$, where δ is small, has been investigated with the shock tube and interferometer. The wave configuration and the pressure along the wall are compared with the theory developed by Lighthill. The results are in qualitative agreement and they indicate that the theory is correct for vanishingly small δ. The density field is also given. From authors' summary

3272. Keller, J. B., Multiple shock reflection in corners, *J. appl. Phys.* **25,** 5, 588–590, May 1954.

Author points out that there are cases where shocks entering a corner from the concave side are reflected regularly without diffraction. For air, this is limited to shocks of small strength and corner angles slightly greater than $\pi/2$.

Y. H. Kuo, USA

3273. Alpher, R. A., and Rubin, R. J., Normal reflection of shock waves from moving boundaries, *J. appl. Phys.* **25,** 3, 395–399, Mar. 1954.

Authors treat a variation of the head-on collision of two plane shock waves [see AMR **6**, Rev. 2841] by considering the subsequent reflection of one of the transmitted shock waves from an advancing piston.

The interaction of a shock wave and a sound wave is developed as a limiting case. I. I. Glass, Canada

3274. Birk, M., Erez, A., Manheimer, Y., and Nahmani, G., Electric conductivity of shock and detonation waves and the measurement of wave velocity (in French), *C. R. Acad. Sci. Paris* **238,** 6, 654–655, Feb. 1954.

Authors describe briefly their use of electric probes to determine the velocity of the shock wave generated by a detonating explosive charge. Ionization within the shock wave closes an electric circuit, which causes a temporary extinction of a spot on a sweeping spiral oscilloscope. In one test, 19 individual probes were used simultaneously and a good time-vs.-distance curve obtained. Use of the method is limited to regions close to the charge, where very high pressures exist. They also found that the current picked up by a probe embedded in a detonating explosive is a linear function of pressure.

J. S. Rinehart, USA

3275. Brown, W. F., and Thomas, T. Y., Rear shock and pressure on supersonic airfoils, *Proc. nat. Acad. Sci. Wash.* 40, 2, 83–87, Feb. 1954.

Well-known expression for pressure change through shock in terms of deflection angle of streamline is garbed in formal argument to obtain approximate formulas for pressure on rear of supersonic airfoil as function of local surface angle ω. Reviewer suggests well-known Prandtl-Meyer expansion is simpler to use (result tabulated) to same degree of approximation (up to terms of order ω^3), and shock-expansion method for higher approximation. J. S. Isenberg, USA

3276. Hermann, R., The decay of weak oblique shock waves in two-dimensional supersonic flow, Proc. Third Midwestern Conf. Fluid Mech., Univ. of Minn., 335–352, 1953.

3277. Legras, J., New applications of Lighthill's method to the study of shock waves (in French), *ONERA Publ.* no. 66, 62 pp., 1953.

Lighthill's general method of approximate solutions [AMR 3, Rev. 1829] is clearly explained for the simple equation $(x + \alpha y)\, y' + y = 1$ where α is a very small parameter; the usual series expansion breaks down for $x = 0$, but a first approximation is obtained by parametric representation of the variables. First application is made to the two-dimensional field far from a symmetrical body in steady supersonic flow; solution at infinity is asymptotic to the field of plane waves. Entire shock field is then calculated in first and second approximation. Special

forms of the obstacle are studied, double parabolic arc, diamond-shaped airfoil, scoop, all for zero angle of attack. Included are numerical computations of perturbation velocities and shocks. Flow field about a rectangular plate which is partly outside, partly inside the Mach cone is investigated. Lighthill's method [AMR 3, Rev. 2405] permits calculating the field outside the arcs where plane and conical shocks intersect; author extends this method to the velocity field in the immediate neighborhood of the intersections and shows the discontinuity in the shock cone.

Analysis of orders of magnitude and convergence of series shows in which cases linearized theory, first approximation, modified first approximation, or second approximation are required. G. R. Graetzer, USA

3278. **Marchal, R., On the conditions for the appearance of shock waves in plane steady spiral flow** (in French), *C. R. Acad. Sci. Paris* **237,** 22, 1392–1394, Nov. 1953.

This short note discusses flow produced by a combined source and vortex. Outside a given circle, three types of flow are possible: (a) Spiral subsonic flow with $M \to 0$ as $r \to \infty$; (b) supersonic flow throughout; (c) flow with circular stationary shocks. In the last case, where radial Mach number must be greater than 1, relations for streamlines and pressure are given.

W. Griffith, USA

3279. **Mair, W. A., Supersonic gas flow,** *Brit. J. appl. Phys.* 5, 1, 1–6, Jan. 1954.

An introduction to supersonic gas flow is given, with emphasis on the features that distinguish supersonic from subsonic flow. Experimental methods for the study of supersonic flow are briefly considered and some simple flows are described.

From author's summary

3280. **Woods, L. C., Phil, D., and Thom, A., A new relaxational treatment of the compressible two-dimensional flow about an aerofoil with circulation,** *Aero. Res. Counc. Lond. Rep. Mem.* 2727, 17 pp., Mar. 1950, published 1953.

The two-dimensional incompressible and compressible flow over a profile is computed by relaxation in a grid with potential and stream function as independent variables. Thus the profile appears as a straight line. Circulation is chosen in advance; angle of attack is found at the end of the computations. Boundary conditions at the profile are taken into account by successive approximations. Known circulation is used to formulate an approximate boundary condition at the outer edge of the relaxation field. Treatment of stagnation region is discussed in AMR **6,** Rev. 1310. Comparison of theoretical and experimental results is carried out for profile NACA 16.

G. Guderley, USA

3281. **Graham, E. W., and Walker, K., Jr., The pressure distribution on a body of revolution in a free jet at Mach number of unity,** *Douglas Aircr. Co. Rep.* no. SM-14913, 9 pp., Sept. 1953.

Linearized potential theory breaks down for sonic flow past an object in an infinite fluid. However, A. Busemann [AMR **5,** Rev. 3169] showed that such cases can be handled if the fluid is bounded laterally by a "free" surface. For axial symmetry, authors use a "free" jet of radius r_0, then obtain first- and second-order solutions, ϕ_1 and ϕ_2, to the velocity potential, setting $\phi_1 = \phi_2 = 0$ at $r = r_0$. They estimate maximum permissible r_0 for first-order solution as case where $\phi_{1r} \to \phi_{2r}$ at $r = r_0$. For a sinusoidal-profile body of half-wave-length L and maximum radius R, the maximum $r_0 \to 0.065\ L^2/R$. The pressure coefficient for any body of revolution, evaluated from ϕ_1, is $-(2\pi)^{-1}\{S''[\ln(S/\pi r_0^2)] + S'^2/2S\}$ where S is the cross-sectional area and primes denote differentiation. Without citing data, authors claim reasonably good agreement of theory with experiments for one smooth slender body. Reviewer feels development is valid and interesting, but needs refinement or experimental adjustment because of its severe approximation.

R. R. Hughes, USA

3282. **Beastall, D., and Pallant, R. J., Wind-tunnel tests on two-dimensional supersonic aerofoils at $M = 1.86$ and $M = 2.48$,** *Aero. Res. Counc. Lond. Rep. Mem.* no. 2800, 20 pp., July 1950, published 1954.

Wind-tunnel tests, at Mach numbers 1.86 and 2.48, have been carried out on two-dimensional unswept double-wedge and circular-arc airfoils to study the viscous effects which are not accounted for in the linearized and shock-expansion airfoil theories. The airfoil characteristics derived from the measured surface pressures are compared with the theoretical values.

Schlieren observation was employed to examine the flow and, in particular, the separation near the trailing edges of the airfoils. In an appendix, the results obtained from experiments on breakaway caused by a step on a flat plate are applied to the airfoil tests as a method of assessing the pressures in the dead-water regions formed by the flow separation, and comparison is made with the measured pressures.

Disturbing the boundary layer by means of wires caused a delay in separation; pitot-tube traverses through the boundary layers with and without wires illustrated the change in velocity profile between the two cases. The position of separation was briefly examined also by the use of oil; the point of separation as indicated by this method was in fair agreement with that given by pressure measurements, for cases of considerable separation only. From authors' summary

3283. **Maillet, E., and Le Manach, J., Wall effects in finite compressor-blade cascades** (in French), *Rech. aéro.* **36,** 13–24, Nov.-Dec. 1953.

Plane cascade and actual compressor tests commonly show good agreement when moderate compression ratios and sufficient cascade length are used. Notable discrepancies appear, however, from high aerodynamic blade loadings and increasing Mach numbers. Mean perturbations arise from flow-stalling on suction side of the first cascade blade. Resulting nonperiodic variations of incidence, velocity, and pressure distribution on blade surface are analyzed experimentally and some means to reduce them are considered: (1) increasing blade number of the cascade; (2) displacing the test section eccentrically; (3) blowing and suction of the boundary layer at tunnel walls.

A comparison of the studied techniques is presented, suction and blowing proving to be the most efficient ones.

P. Schwaar, France

3284. **Wallace, F. J., and Mitchell, R. W. S., Wave action following the sudden release of air through an engine port system,** *Instn. mech. Engrs. Proc. (B)* **1B,** 8, 343–356, 1952–1953.

A ported opposed-piston engine liner, discharging cold air through exhaust ports into conventional exhaust system, is considered. Ports are sealed by cellophane membranes which, if pierced, give a sudden discharge. Process of discharge, wave propagation in exhaust pipe, and partial evacuation of cylinder by returning rarefaction wave are analyzed by methods developed in AMR **2,** Rev. 1524. Good agreement between experimental and theoretical investigations is obtained. Coefficient of discharge of exhaust ports is examined under different release conditions, and a relation based on dimensional analysis is established from which

a discharge coefficient for given operating conditions may be deduced. From authors' summary by G. Guderley, USA

Turbulence, Boundary Layer, etc.

(See also Revs. 3254, 3255, 3313, 3328, 3355, 3357, 3396, 3422)

3285. Taylor, G., The dispersion of matter in turbulent flow through a pipe, *Proc. roy. Soc. Lond.* (*A*) **223,** 1155, 446–468, May 1954.

The dispersion of soluble matter introduced into a slow stream of solvent in a capillary tube can be described by means of a virtual coefficient of diffusion [title source **219,** 186, 1953] which represents the combined action of variation of velocity over the cross section of the tube and molecular diffusion in a radial direction. The analogous problem of dispersion in turbulent flow can be solved in the same way. In that case the virtual coefficient of diffusion K is found to be $10{\cdot}1av_*$ or $K = 7{\cdot}14aU(\gamma)^{1/2}$. Here a is the radius of the pipe, U the mean flow velocity, γ the resistance coefficient, and v_* "friction velocity."

Experiments are described in which brine was injected into a straight $^3/_8$-in. pipe and the conductivity recorded at a point downstream. The theoretical prediction was verified with both smooth and very rough pipes. A small amount of curvature was found to increase the dispersion greatly.

When a fluid is forced into a pipe already full of another fluid with which it can mix, the interface spreads through a length S as it passes down the pipe. When the interface has moved through a distance X, theory leads to the formula $S^2 = 437aX(v_*/U)$. Good agreement is found when this prediction is compared with experiments made in long pipe lines in America.

From author's summary by S. I. Pai, USA

3286. Kovasznay, L. S. G., Turbulence in supersonic flow, *J. aero. Sci.* **20,** 10, 657–674, 682, Oct. 1953.

Equations for small fluctuations in a viscous, heat-conducting medium are shown in linearized approximation to be separable in three modes: vorticity (turbulence), pressure (sound), and entropy (decay of temperature spots by heat conduction). Second-order approximation gives 18 interaction terms between these modes. Hot-wire anemometer responds to mass flow m and stagnation temperature θ fluctuations, hence density, velocity and temperature fluctuations contribute (but not pressure). By measuring under different hot-wire conditions, sensitivity to m and θ is determined.

Each mode gives typical fluctuation diagram, easily derived for temperature and entropy. For sound waves, only waves that are almost Mach waves are considered; it is expected that contributions from other waves are negligible. In actual flow, all three modes are present; in special cases (no sound waves, uncorrelated modes), they can be separated. Experiments are analyzed: (1) Oscillations of weak shock waves (sound waves); (2) turbulent boundary layers (sound waves negligible compared to vorticity; fluctuation field is similar to low-speed boundary layer, except for entropy fluctuations, of same order as vorticity).

R. Timman, Holland

3287. Pankhurst, R. C., Thwaites, B., with an appendix by Walker, W. S., Experiments on the flow past a porous circular cylinder fitted with a Thwaites flap, *Aero. Res. Counc. Lond. Rep. Mem.* 2787, 28 pp., Oct. 1950, published 1953.

Distributed suction effectively prevented boundary-layer separation and enabled a close approximation to potential flow to be achieved. The flap was essential to the attainment of steady-flow conditions with suction; without a flap the pressure distribution fluctuated. For a given Reynolds number, the minimum suction quantity needed to prevent separation decreased with increasing flap chord. At small flap deflections, the wake could be completely suppressed.

G. E. Nitzberg, USA

3288. Chapman, D. R., and Kester, R. H., Turbulent boundary-layer and skin-friction measurements in axial flow along cylinders at Mach numbers between 0.5 and 3.6, *NACA TN* 3097, 53 pp., Mar. 1954.

Experiments have been conducted to determine average skin-friction coefficients in the absence of heat transfer for completely turbulent flow along the cylindrical portion of cone-cylinder bodies of revolution having over-all fineness ratios of 10, 15, and 25. The friction data were obtained by directly measuring forces. Mach numbers of 0.5, 0.8, 2.0, 2.5, 2.9, 3.4, and 3.6, and Reynolds numbers between 4 million and 32 million were investigated. At both subsonic and supersonic velocities, the skin-friction coefficient depends only to a small extent on cylinder length-diameter ratio. For each length-diameter ratio, however, the effect of Mach number is large, amounting to approximately a 50% reduction in skin-friction coefficient as the Mach number is increased from 0 to 4. This effect of Mach number does not depend significantly on Reynolds number or cylinder fineness ratio. Comparison with similar experiments on flat plates, primarily those of Coles, shows good agreement as to the effect of Mach number on skin friction, although the velocity profiles measured on cylinders are appreciably different from those on a flat plate. Determinations of friction by the momentum method differed considerably from the more reliable direct-force measurement. From authors' summary

Reviewer's comment: An excellent introduction gives a survey of the status of experimental and theoretical investigations in compressible and incompressible fluids and extends it to include the case of high Mach number flow. A full bibliography is also given. Testing techniques are fully described, all assumptions clearly stated, and such possible sources of error as tunnel turbulence, pressure gradient, nose shape, and boundary-layer transition are carefully explored. Results are compared with those of many other investigators. Ione D. V. Faro, USA

3289. Lange, R. H., Present status of information relative to the prediction of shock-induced boundary-layer separation, *NACA TN* 3065, 16 pp., Feb. 1954.

A brief summary is given of the data relating to the shock-wave pressure ratios to induce separation of the laminar boundary layer on a flat plate over a range of Mach number and Reynolds number. The corresponding data for a turbulent boundary layer include results obtained from experiments on flat plates and ahead of vertical steps and inclined wedges. The data relate only to two-dimensional flows.

The strong dependence of Reynolds number on the laminar and the weak dependence of Reynolds number on the turbulent boundary-layer results are noted, but insufficient data preclude an accurate quantitative assessment of this important effect. It is shown that insufficient experimental results are at present available to safely predict the pressure ratio for shock-induced boundary-layer separation on configurations differing considerably from those for which experimental results exist.

The recent work at the N.P.L. England is not reviewed.

G. M. Lilley, England

3290. Mackay, D. S., and Nagamatsu, H. T., Laminar boundary-layer temperature recovery factor on a cone at nominal Mach number six, *J. aero. Sci.* **21,** 1, 65–66, Jan. 1954.

The local temperature recovery factor for a cone with a laminar

boundary layer was determined as 0.844 from wind-tunnel tests at stream Mach numbers from 5.6 to 5.9 and Reynolds numbers from 21,000 to 540,000. E. B. Klunker, USA

3291. **Smith, J. W., A note on the effect of diffusion fields on the laminar boundary layer,** *J. aero Sci.* **20,** 12, 847–848, Dec. 1953.

Equations for diffusion field in laminar, compressible boundary-layer flow past flat plate are established. Case wherein similarity parameter $\eta \sim yx^{-1/2}$ can be used is studied. This implies restrictions on conditions at wall of a familiar type. Physical properties are treated as functions of local concentrations. Problem is restated in form of integral equations, solved by method of successive approximations. Results of application to flat plate in air when $M = 8$ and with plate-to-free-stream-temperature ratio of 6, without and with helium introduced near wall, are noted. Thermal and dynamical boundary conditions are considered unchanged in both cases. Evaporation of helium reverses heat transfer at wall. M. Finston, USA

3292. **Moore, F. K., Laminar boundary layer on cone in supersonic flow at large angle of attack,** *NACA Rep.* 1132, 13 pp., 1953.

Supersedes article reviewed in AMR **6,** Rev. 1978.

3293. **Conkie, W. R., and Savic, P., Calculation of the influence of internal circulation in a liquid drop on heat transfer and drag,** *Nat. Res. Counc. Canad. mech. Engng. Rep.* no. MT-23, 20 pp., Oct. 1953.

Under certain circumstances, circulation may exist in a liquid drop in motion through a viscous medium. This report develops an expression for the reduced boundary-layer thickness resulting from circulation, for highly idealized conditions outside of Stokes' regime, using a mathematical artifice from slip flow theory. Reynolds analogy between heat transfer and skin friction is applied to indicate substantial increase in film heat-transfer coefficient due to circulation. An estimation of effect of circulation on drag is attempted. A limited amount of experimental data is presented which seem to support implications of the analysis, and need is pointed up for more such data. W. Rice, USA

Aerodynamics of Flight; Wind Forces

(See also Revs. 3275, 3278, 3280, 3283, 3293, 3310, 3312, 3313, 3332, 3352, 3354, 3399, 3400, 3401, 3402, 3403, 3404, 3424)

3294. **Cescotti, R., Aviation dictionary [Luftfahrt-Wörterbuch],** München, Hanns Reich Verlag, 1954, 448 pp. $3.30.

This German-English, English-German dictionary contains 30,000 terms of aeronautics and allied subjects; pronunciation in English-German part is in phonetic transcription as recommended by the International Phonetic Association. The dictionary also contains a list of abbreviations, a comprehensive alphabetic list of factors, and seven tables for conversion of American and British units of measurement into metric units, and vice versa. Ed.

3295. **Cooper, M., and Grant, F. C., Minimum-wave-drag airfoil sections for arrow wings,** *NACA TN* 3183, 26 pp., May 1954.

A linearized theoretical analysis has been made to determine minimum-wave-drag airfoil sections for arrow wings having the same airfoil sections at all spanwise stations. The drag of the wings was minimized subject to the condition of either a given thickness ratio at a specific chordwise location or a given volume. Numerical computations of the airfoil shape and wing wave drag were performed for a delta wing and for an arrow wing having a ratio of the tangent of the trailing-edge sweep angle to the tangent of the leading-edge sweep angle of 0.4. The range of the ratio of the tangent of the leading-edge sweep angle to the tangent of the Mach line sweep angle extended from 0 (two-dimensional) to 2.5. From authors' summary

3296. **Mirels, H., Aerodynamics of slender wings and wing-body combinations having swept trailing edges,** *NACA TN* 3105, 96 pp., Mar. 1954.

A general method, based on two-dimensional cross-flow concepts, is presented for obtaining the lift and moments on highly swept wings. Emphasis is placed on obtaining solutions for wings having swept trailing edges. The method is applicable for all problems where the velocity boundary conditions can be made homogeneous by differentiation in the streamwise or spanwise directions. Lift, roll, and pitch solutions for highly swept wings are presented. Both direct problems and inverse problems are considered. Applications of the method for the solution of wing-body problems and unsteady two-dimensional incompressible-flow problems are also indicated.

From author's summary by H. P. Liepman, USA

3297. **Howe, D., Testing and analysis of a 60° sweptback wing with ribs parallel to the line of flight,** *Coll. Aero. Cranfield Rep.* 66, 20 pp., 4 tables, 60 figs., Aug. 1953.

Test results are presented for a 60° sweptback wing specimen having closely spaced ribs parallel to the line of flight. The aspect ratio was 2.45, the semispan was 101.5 in., and the taper ratio was 1.5. The wing root was held in reinforced concrete. Bending, torsion, and shear loads were applied. Appreciable distortion of the oblique ribs was evident, particularly for torsional loading. Good agreement with an oblique coordinate theory is found for the strains away from the root. Near the root, the stresses build up toward the rear spar and are not in agreement with the theory used. S. Levy, USA

3298. **Arabian, D. D., Hydrodynamic directional behavior of a swept planing-tail hull,** *NACA RM* L51F04, 15 pp., Jan. 1952. (Declassified from Confidential Mar. 9, 1954.)

3299. **Goodman, A., and Thomas, D. F., Jr., Effects of wing position and fuselage size on the low-speed static and rolling stability characteristics of a delta-wing model,** *NACA TN* 3036, 66 pp., Feb. 1954.

Paper describes low-speed experimental study of delta-wing airplane model's static longitudinal, static lateral, and rolling stability. Model had delta vertical and no horizontal tail and was tested with a variety of fuselage sizes and wing positions. Tuft grid pictures and other data of assistance to stability and control engineers are presented. H. Luskin, USA

3300. **Canning, T. N., A simple mechanical analogue for studying the dynamic stability of aircraft having nonlinear moment characteristics,** *NACA TN* 3125, 18 pp., Feb. 1954.

Analogy is developed between a ball rolling over a curved surface and an airplane, with nonlinear moment characteristics, pitching and yawing in flight. This analog was devised to investigate a peculiar motion executed by a missile in the Ames supersonic free-flight tunnel. Test results from a model with linear moment characteristics are presented to verify the analogy, and examples of nonlinear systems are also given.

Reviewer considers analog ingenious but notices confusion of mathematical argument and considers that absence of scales from all graphs detracts from their usefulness.

Relation between the vector sum of the pitching and yawing moment coefficients $\mathbf{C}_\sigma$ and the coordinate z of a point on the curved surface should be $\mathbf{C}_\sigma = \text{grad } z$ where $\mathbf{C}_\sigma = \mathbf{C}_m\mathbf{i} + \mathbf{C}_n\mathbf{j}$ and $\sigma = \alpha\mathbf{i} + \beta\mathbf{j}$ is the vector sum of the angles of attack and sideslip (cf. p. 2). Thus the equation at bottom of page 5 should be replaced by the vector relation $\mathbf{C}_\sigma = (C + D\sigma\cdot\sigma)\sigma$. On page 5, it is also necessary that $l_1 = l_2$. S. Kirkby, England

3301. de Kraskinski, J. E., Proposal of a criterion for longitudinal stability of swept wings in stall conditions (in Spanish), *Comun. Inform. Escuela super. Aerotecn. Cordoba* C-6, 34 pp., 1953.

By analyzing 40 swept wings, measured in various wind tunnels, and determining the spanwise distribution by the Weissinger theory, the condition $(\eta_{C_{L\max}} - \eta_{CP})$ tg $\Lambda < 0.063$ has been obtained ($\eta_{C_{L\max}}$ is the nondimensional abscissa on the half-wing at which the maximum local C_L is attained, η_{CP} is the abscissa of the center of pressure, Λ is the angle of sweep). This expression is valid for the longitudinal static stability in the stall of sweptback wings of moderate aspect ratio (wings of no. I class).

By denoting by A the aspect ratio and by λ the taper ratio, the above condition can be generalized as $f(A, \lambda, \Lambda) < 0.063$; the curves corresponding to such condition are given in the paper. If the proposed critierion be simplified by neglecting the effect of taper ratio, a good correlation with Shortal's empirical curve is obtained. The criterion being proposed is probably limited by the system of vortex flow originated by pronounced sweepback angles and small nose radii. Wings with pronounced taper ratios (approximately $\lambda = 0.15$; wings of class no. II) seem to have practically indifferent stability in stalling conditions, provided that the sweepback angle of the trailing edge is not too pronounced. Such wings present a certain extension of the "delta wing" and could be of great interest for fast aircraft with heavy payload, since they have the properties of elliptic lift distribution and combine comparatively high angles of sweep with high aspect ratios. As the experimental evidence is scarce, more tests are needed for this class of wings.

From author's summary by P. Santini, Italy

3302. Jewel, J. W., Jr., and Carpenter, P. J., A preliminary investigation of the effects of gusty air on helicopter-blade bending moments, *NACA TN* 3074, 28 pp., Mar. 1954.

A preliminary investigation has been made at the Langley helicopter test tower to determine the bending moments excited on typical helicopter blades in quiet and gusty air. The results obtained from the limited range of this investigation indicate that the effects of gusts on rotor-blade bending moments appear to be secondary when compared with the vibratory moments attributed to the unsymmetrical rotor downwash for the 26-mph wind-velocity condition tested and analyzed. It was also found that the addition of weight at the blade tips reduced the magnitude of the blade vibratory bending moments.

From authors' summary

3303. Summers, R. G., On determining the additional apparent mass of a wing-body-tail cross section, *J. aero. Sci.* **20,** 12, 856–857, Dec. 1953.

3304. Rutowski, E. S., Energy approach to the general aircraft performance problem, *J. aero. Sci.* **21,** 3, 187–195, Mar. 1954.

See AMR **7,** Rev. 874.

3305. Baxter, J. R., An analysis of the steady climbing turn without sideslip, *Aero. Res. Labs. Melbourne, Austral. Rep.* A.81, 31 pp., Dec. 1952.

The geometry of the system and the equilibrium of the principal forces are completely analyzed without approximations, and the six equations of motion are set out in their accurate dimensional form. Then, introducing a series of approximations, the various equations are simplified and solved. The solutions are used to derive expressions for the two maneuverability criteria, stick movement and stick force per g, and comparisons are made with the equivalent criteria for the pull-out case.

From author's summary

3306. Crim, A. D., Reeder, J. P., and Whitten, J. B., Initial results of instrument-flying trials conducted in a single-rotor helicopter, *NACA Rep.* 1137, 7 pp., 1953.

3307. O'Hara, F., and Mather, H. A., The performance after power failure of a helicopter with blade pitch control, Parts I and II, *Aero. Res. Counc. Lond. Rep. Mem.* 2797, 16 pp., Sept. 1951, published 1953.

3308. Foss, K. A., and Diederich, F. W., Charts and approximate formulas for the estimation of aeroelastic effects on the lateral control of swept and unswept wings, *NACA Rep.* 1139, 25 pp., 1953.

Supersedes article reviewed in AMR **6,** Rev. 1028.

Aeroelasticity (Flutter, Divergence, etc.)

(See also Revs. 3299, 3301, 3303, 3308)

3309. de Jager, E. M., The aerodynamic forces and moments on an oscillating aerofoil with control-surface between two parallel walls, *Nat. LuchtLab. Amsterdam Rap.* F.140, 15 pp., 16 figs., Oct. 1953.

This is an extension of Timman's report reviewed in AMR 5, Rev. 766. The method is similar to that of Theodorsen for the velocity potential of a free airfoil. The perturbation potential of an airfoil in two-dimensional incompressible flow is split up into two parts, a regular part due to the motion of the airfoil and a singular part due to the vortexes in the wake.

Numerical results are given for wing and control-surface derivatives for various values of wing chord/tunnel height for a range of frequency parameters ω and control-surface chords. The corrections due to the tunnel walls have maximum values for ω between 0.1 and 0.3, these maxima being considerably larger than the corrections in the static case due to the reflection of the wake vortexes. The main part of these corrections for this range of ω can be obtained by modifying the circulation function in the expression for the derivatives of a wing-control system in a free air stream. A. W. Babister, Scotland

3310. Hedgepeth, J. M., and Kell, R. J., Rolling effectiveness and aileron reversal of rectangular wings at supersonic speeds, *NACA TN* 3067, 79 pp., Apr. 1954.

Paper is an attempt to formulate a practical method for dealing with certain aeroelastic problems. Particularly, the proposed method is aimed at the solution of those problems where beam theory for structural deformations and strip theory for aerodynamic forces may not be adequate. The formulation is made by matrix algebra in terms of structural influence coefficients and aerodynamic influence functions. A numerical example is presented to illustrate the method, and comparison is made with two simplified methods.

Reviewer considers paper to be an important one because the method presented appears to be well suited to extensions to problems other than the specific one stated in the title, as authors

point out; extension of method to flutter problems of low-aspect-ratio nonrectangular wings is an intriguing possibility. Paper is heartily recommended to all those engaged in computation or analysis of aeroelastic behavior of supersonic wings.

H. N. Abramson, USA

3311. **Woolston, D. S., and Huckel, Vera, A calculation study of wing-aileron flutter in two degrees of freedom for two-dimensional supersonic flow,** *NACA TN* 3160, 26 pp., Apr. 1954.

Results are presented of some sample calculations made for the bending-aileron and torsion-aileron flutter of an idealized wing-aileron system (infinite aspect ratio, full-span aileron hinged at its leading edge) for several values of Mach number in supersonic flow and also for some subsonic Mach numbers. The more influential parameters appear to be: mass balance of the control surface, control-surface frequency relative to wing frequency, and structural damping. An interesting result is the indication of an apparent reverse effect of mass balance at the transonic speeds for some wing-aileron configurations. A high value of control-surface frequency appears beneficial, as does structural damping of the system. In several of the calculations, the possibility of flutter in a single degree of freedom is indicated. From authors' summary

3312. **Nelson, H. C., Rainey, Ruby A., and Watkins, C. E., Lift and moment coefficients expanded to the seventh power of frequency for oscillating rectangular wings in supersonic flow and applied to a specific flutter problem,** *NACA TN* 3076, 53 pp., Apr. 1954.

Stewartson's method [AMR **4**, Rev. 2121] is used to calculate lift and moment coefficients for oscillating rectangular wings in supersonic flow. The results are applied to a flutter analysis for uniform cantilever wing. Flutter speeds were obtained in the Mach number range from 10/9 to 10/6 for a rectangular wing of aspect ratio 4.53.

From authors' summary by S. I. Pai, USA

Propellers, Fans, Turbines, Pumps, etc.

(See also Revs. 3250, 3262, 3282, 3302, 3330, 3332, 3375, 3388, 3392, 3399, 3408)

3313. **Iura, T., and Rannie, W. D., Experimental investigations of propagating stall in axial-flow compressors,** *Trans. ASME* **76,** 3, 463–471, Apr. 1954.

Paper describes stall propagation in three-stage subsonic axial compressor with free vortex blading. Authors stress the importance of this phenomenon as a possible cause of blade failures. Measurements were made with two hot wires and pen recorder, the frequency response of the apparatus being adequate for the results presented.

Occurrence of propagating stall is correlated with pressure and temperature-rise characteristics. As flow was reduced, one, two, and three stall cells were found at the blade hub. Each rotated at 38% of the rotor angular velocity and covered half the blade height. This is designated "partial stall." By contrast, "full stall" is defined as occurring at lower flows when one cell, covering the whole blade height and a fraction of the circumference, rotated at 28% of rotor velocity. This single cell persisted until zero flow was reached. Additional tests on single stages of free vortex and solid body blading show partial stall initiated at blade tip.

Reviewer believes that initiation of partial stall is dependent on mean local blade flow conditions since, from his own experimental work, propagating stall can occur in a single stage either at the stator hub or, at a different flow, at the rotor tip.

M. D. Wood, England

3314. **Baron, S., Detect boiler feed pump load-drop cavitation mathematically,** *Power Engng.* **58,** 5, 69–72, May 1954.

3315. **Acosta, A. J., Potential flow through radial flow turbomachine rotors,** *Hydrodynamics Lab., Calif. Inst. Technol., Rep.* E-19.4, 53 pp., Feb. 1954.

The exact theory of incompressible potential flow through pump impellers with logarithmic spiral (constant angle) blades is extended to include radial or conical turbomachines with small variations in vane angle and passage breadth. Approximate formulas are obtained and charts given for smooth entry and performance characteristics of pump or turbine configurations when the solidity is somewhat greater than unity and when the major blade deviations are confined to the inlet regions. However, the results of the present analysis are general and may be applied to blade rows with reasonably arbitrary camber lines.

R. C. Binder, USA

3316. **McCoy, A. W., and Brunner, M. J., The use of stator-blade control to obtain wide range of compressor performance for wind-tunnel application,** *Trans. ASME* **76,** 2, 233–240, Feb. 1954.

Axial-flow compressors with fixed blades are subject to the disadvantage that even small change of volume flow at constant speed usually causes relatively large change of pressure ratio and efficiency. Since this results from increased divergence between blade angle and theoretical fluid angle, effects can be avoided by adjusting blade angle to suit fluid angle, though at cost of mechanical complication. For convenience, stator rather than rotor angle is usually varied. Paper presents requirements of blading designed for such variation, and concludes that design for constant tangential component of fluid velocity at all radii is better for adjustable blades than design for variation of tangential component either directly or inversely with radius. One empirical and two analytical methods of predicting performance are described, one of latter taking account of radial equilibrium, the other basing calculation on conditions at mean radius only. Tests of three-stage unit demonstrated possibility of varying volume flow over 2:1 range with minimum efficiency of 80%, and showed performance can be predicted with reasonable accuracy by analytical methods. C. W. Smith, USA

3317. **Cole, B. N., and Mills, B., The theory of sudden enlargements applied to the poppet exhaust-valve, with special reference to exhaust-pulse scavenging,** *Instn. mech. Engrs. Proc. (B)* **1B,** 8, 364–377, 1952–1953.

Authors state that the poppet type of valve mounted in the cylinder head is the best suited for two-stroke internal-combustion engines. To find optimum design configurations, equivalent experiments with compressed and heated air were performed. These experiments consisted of: (1) Measurements of steady flow through a nozzle followed by a sudden enlargement. (2) Comparative tests with a full-scale poppet-valve model, using incompressible flow only, in order to determine the optimum proportions of valve head and seat. (3) Compressible flow tests using optimum proportions in full- and half-scale valve models. Analyses of flow of a gas through the "sudden enlargement system" were carried out for incompressible, subsonic compressible, and for two cases of compressible flows, namely, (a) where sonic velocity is reached in the throat and (b) where the flow downstream of the throat "at the position at which the issuing vein has expanded to the full exhaust pipe bore (or to the pipe bore at entry to any attached diffuser cone) also becomes sonic."

The analysis, as presented, gives the impression that authors are not familiar with the wealth of literature available dealing with one-dimensional flows. By studying this literature, authors should have noticed that one-dimensional treatment is valid only for problems where the gradient of the flow variables (including cross-sectional area variation!) is gradual. Therefore, one-dimensional analyses are not applicable to cases with sudden enlargement in the cross-sectional area. Introduction of the "trailing face pressure" and assumptions about its magnitude obviously will lead to false relationships (see, e.g., Eq. 32, which is wrong). It is indeed with "some suspicion," as the authors put it, that Eq. 32 should be regarded. Reviewer thinks that this refers to the whole analysis presented. It would have been better to present the experimental results alone, which—if accurate—would help designers of poppet valves. T. P. Torda, USA

3318. Lasley, R. A., and Lewis, F. M., The development of high-output free-piston gas generators, *Trans. ASME* **76,** 3, 453–461, Apr. 1954.

3319. Trassl, W., and Wilck, A. F., Correlation of the main factors in practical reheating processes (in German), *Brennstoff-Wärme-Kraft* **6,** 2, 44–51, Feb. 1954.

The effect of the principal quantities on the thermal utilization of reheat in steam-power installations is examined. The efficiency of the turbine depends, of course, on the temperature and pressure of the fresh steam, the temperatures of the reheat and the cooling water, and on the method of regeneration; besides these, the effect of the reheat pressure is shown to be appreciable. The changes in the thermal processes and the variation in the turbine efficiency—both high-pressure and low-pressure part—are examined, and optimum values for the reheat pressure are calculated for several states of the fresh steam and for various temperatures of the reheat. From authors' summary by W. Hitschfeld, Canada

Flow and Flight Test Techniques

(See also Revs. 3359, 3366, 3379, 3438)

3320. Schröder, E., Double nozzle, a new flow-measuring device (in German), *ZVDI* **96,** 11/12, 347–348, Apr. 1954.

The instrument described consists of a normal short venturi inlet followed by a diffuser whose minimum diameter is somewhat smaller than the inlet minimum diameter. The pressure drop is measured between the upstream maximum diameter and the entrance to the second nozzle. Experiments indicate that for the same effective flow area, i.e., the product of flow coefficient and ratio of minimum to maximum area, the effective pressure loss of the new nozzle is about one half that of the equivalent venturi. E. G. Chilton, USA

3321. Calderwood, G. F. N., and Mardles, E. W. J., Viscometry—The meniscus resistance in capillary flow of liquids, *Proc. phys. Soc. London (B)*, **67,** part 5, 413B, 395–400, May 1954.

Experiments, first described by Guy Barr in a paper to the Society on surface tension effects in viscometry, relating to the influence of a wetting agent on flow times in standard viscometers have been traced to meniscus resistance, particularly of the recessional meniscus, the resistance being decreased by wetting agents and increased with increase of contact angle. With a variety of oils of different chemical composition and of different surface characteristics, the reproducibility of viscosity results obtained with standard viscometers and by the procedure laid down in the latest I.P.-A.S.T.M. method varied up to 0.5%, a coefficient of error greater than that usually obtained with mineral oils alone. From authors' summary

3322. Boyer, R. L., Craig, D. R., and Miller, C. D., A photographic study of events in a 14-in. two-cycle gas-engine cylinder, *Trans. ASME* **76,** 1, 97–108, Jan. 1954.

Report gives results of the first high-speed examination of events occurring in a two-cycle gas engine with 14-in. bore and 14-in. stroke. Glass windows in cylinder and stellite mirrors in cylinder and on the top of piston are parts of a schlieren system, allowing for taking of motion pictures by a camera especially designed for that purpose. From slow-motion projection, the average velocities of gas during combustion, exhaust blowdown, scavenging, and fuel injection are determined both in magnitude and direction; the single stages of combustion were referred to the crank angle.

Scavenging air was found to enter in a high-speed turbulent jet, while the exhaust is laminar. Turbulence causes some difference in the laminar scavenging process assumed for cylinder design. This difference is not so important in the case of loop scavenging as it is for uniflow scavenging. The usual assumption of a "laminar air piston" is, therefore, not valid.

H. Krüger, Germany

3323. Bourot, J.-M., Chronophotographical methods for measurement of fluid vibrations (in French), *Publ. sci. tech. Min. Air, Paris* no. 264, 79 pp., 1952.

Author investigates both theoretically and experimentally the possibility of studying fluid vibrations by means of photographing with a moving camera solid particles suspended in the fluid. Since the solid particles possess properties which are different from those of the fluid, they will not in general follow the fluid motion exactly. The error introduced by this is evaluated approximately and discussed in detail. Under the condition that the suspended particles are small enough that Stokes flow for the relative motion can be assumed, the significant parameters, density ratio, and "propulsion coefficient" are found. The latter is related to the first and the limiting fall velocity of the particle. The suitability of several materials is investigated. Carbonate of magnesia is found to yield excellent results. The theory is applied to obtain the fidelity of reproduction of oscillatory motions. The experimental part of this work contains excellent photographs of oscillation in air produced by means of the organ pipe and the loud-speaker. P. F. Maeder, USA

3324. de Krasinski, J. E., and Nawalany, T., A micromanometer with zero indication and of high pressure range (320 mm H_2O) (in Spanish), *Comun. Inform. Escuela super. Aerotech. Cordoba* **T-2,** 9 pp., 1953.

A micromanometer of wide pressure range (320 mm H_2O) was needed for use at the Aerodynamic Laboratory. An instrument was developed on the principle of Chattock's manometer and a zero indicator was added to it to avoid the danger of the bubble bursting during the tests. Forty measurements made at two different heights of hydrostatic pressure gave a probable error in the estimation of zero of ± 0.0012 mm H_2O, obtained by the least square method. From authors' summary

3325. Rolls, L. S., and Havill, C. D., Method for measuring thrust in flight on afterburner-equipped airplanes, *Aero. Engng. Rev.* **13,** 1, 45–49, Jan. 1954.

Paper presents an experimental technique to determine in flight the net propulsive force acting on an afterburner-equipped airplane by measurement of total and static pressures and stagnation temperature across fuselage exit and free-stream conditions.

The use of a swinging probe is discussed and some typical test results are reviewed. J. C. Wisdom, Australia

3326. **Lukasiewicz, J., Development of intermittent high-speed wind tunnel installations and testing techniques,** *Nat. Aero. Establ. Canad.* LR 75, 53 pp., July 1953.

3327. **Holder, D. W., and North, R. J., The 9 × 3 in. induced flow high-speed wind tunnel at the National Physical Laboratory,** *Aero. Res. Counc. Lond. Rep. Mem.* 2781, 23 pp., June 1949, published 1953.

3328. **Carmichael, B. H., Flight observations of suction-stabilized boundary layers,** *Aero. Engng. Rev.* **13,** 2, 36–42, Feb. 1954.

The experiments were carried out with a sailplane whose wing was prepared as a test section for laminar boundary layers with suction stabilization. On the upper surface the rear part of the NACA 4416 wing section was rendered porous by perforating with a needle. The inner wing of this part was left as a closed compartment in which the internal pressure could be reduced by means of a blower. Flight Reynolds numbers of 2 to 4 million were produced.

The location of the transition for various lift coefficients shows there exist a lower and an upper limit for the internal pressure under which the boundary layer remains laminar. The upper limit results from a too thin boundary layer, which is too sensitive to surface irregularities. Further, for some test points the curves of the boundary-layer parameters are given along the wing chord for two different porosity distributions. In the case of low-porosity surface, the Reynolds number based on the displacement thickness and the local potential velocity reached values of about 3000 without destabilization. Unfortunately, the pressure distributions along the test section are missing.

N. Scholz, Germany

3329. **Gracey, W., and Scheithauer, E. F., Flight investigation at large angles of attack of the static-pressure errors of a service pitot-static tube having a modified orifice configuration,** *NACA TN* 3159, 25 pp., Feb. 1954.

The effect of inclination of the air stream on the static pressure measured by two essentially similar service pitot-static tubes and by one of these tubes with three modified orifice arrangements has been determined in flight. The original orifice configuraton consisted of four orifices on the top of the tube within ±20° of the vertical axis, and six on the bottom within ±30° of the vertical axis. In an attempt to increase the range of insensitivity of the tube to air-stream inclination, this orifice configuration was modified in three successive stages. The best of the modified orifice arrangements involved the addition of one orifice to the bottom of the tube along its center line and the enlargement of the two outermost orifices on the bottom. The tests of this configuration were conducted over an angle-of-attack range of −15° to 45°, at Mach numbers from 0.20 to 0.68, and at Reynolds numbers from 0.9×10^6 to 2.7×10^6 (where Reynolds number is based on the local velocity and the diameter of the tube).

The results of the tests of the best of the orifice arrangements showed that, for Mach numbers between 0.20 and 0.68 and for Reynolds numbers between 0.9×10^6 and 1.4×10^6, the error will remain within 2% of the impact pressure q_c over an angle-of-attack range of −10° to 30°.

At angles of attack between 30° and 45°, the static-pressure error increases rapidly and reaches values as high as 15% of q_c at an angle of attack of 45°. Because of the magnitude of the errors and the fact that the static pressure registered by the tube increases abruptly and erratically at some angle of attack within this range, the usefulness of the tube is limited to angles of attack below 30°. From authors' summary

3330. **Stephenson, J., Shields, R. T., and Bottle, D. W., An investigation into the pitot rake method of measuring turbo jet engine thrust in flight,** *Aero. Res. Counc. Lond. curr. Pap.* no. 143, 55 pp., 1954.

Tests have been made to establish whether a pitot rake could be used as an absolute measure of the thrust of a jet engine on the ground and in flight.

The main conclusions were: Static tubes must be incorporated in the pitot rake to give absolute thrust measurements and, even so, a discrepancy of 2% requires further investigation; the single pitot method of estimating flight thrust based on engine test-bed calibration was in error by as much as 6%, due to changes in total pressure samples by the single pitot and in the magnitude of the exit static pressure between calibration and test conditions; using the pitot static rake to calibrate the single pitot of an installed engine introduced flight thrust errors no larger and possibly smaller; nondimensional thrusts at 35,000 ft were some 7% lower than corresponding thrusts at 5000 ft. Further tests are required to establish the magnitude of these effects on other engine types. From authors' summary

3331. **Skopinski, T. H., Aiken, W. S., Jr., and Huston, W. B., Calibration of strain-gage installations in aircraft structures for the measurement of flight loads,** *NACA TN* 2993, 70 pp., Aug. 1953.

3332. **Mortarino, C., Problems of experimentation on jet-propulsion aircraft models** (in Italian), *Conv. Stud. Propul. Reaz., Milano,* Apr. 1952; *Suppl. Ric. sci.* **22,** 5, 45–58, 1952.

Author briefly examines aerodynamic interference effects resulting from application of power plant (jet or reciprocating engine with airscrew) to airplane, and states that more important interference effects from air flowing through internal ducts in fuselage and wings are to be expected when airplane is powered by a jet engine.

Some typical experiments on models of airplanes with airscrews are mentioned, and particular attention is given to aerodynamic problems involved in application of jet-propulsion power plant and to their solution by experiments on models. An extended list of references is given.

Author concludes with the description of a program and installation scheme relative to experimental research that is to begin at Laboratorio di aeronautica del Politecnico di Torino on the model of a jet-propelled aircraft.

From author's summary

Thermodynamics

(See also Revs. 3208, 3361, 3362, 3364, 3368, 3389)

3333. **Landsberg, P. T., On most probable distributions,** *Proc. nat. Acad. Sci. Wash.* **40,** 3, 149–154, Mar. 1954.

Author considers virtual thermodynamical systems in which the method of the most probable distribution leads to incorrect results, although the use of Stirling's formula is avoided. In some, but not all, of author's examples, mistakes are due to the substitution of a continuous variable for the set of occupation numbers. Author's arguments are not likely to affect any familiar type of thermodynamical system but may obtain significance if the scope of statistical mechanics is extended.

R. Eisenschitz, England

3334. Klein, G., and Prigogine, I., Statistical mechanics of irreversible phenomena III (in French), *Physica* **19,** 11, 1053–1071, Nov. 1953.

Study concerns the statistical mechanics of irreversible processes in linear assemblies of harmonic oscillators where nearest neighbors only are interacting. The equations of motion are solved in terms of the initial conditions of the system and these are subjected to probability distributions. The change of the distribution functions with time is described in some detail and the asymptotic behavior after large time is investigated. Particularly simple asymptotic results can be obtained for infinite systems by restricting the initial distribution function to a product of uncorrelated distribution function of the different variables (velocities, relative distances). The physical significance of such initial factorized distribution functions in terms of normal modes is indicated. It is shown that such distribution functions correspond to initial states for which equipartition of energy between the different normal modes is already achieved. On the other hand, the distribution of phases is initially not the equilibrium random distribution. In this case it can be shown that each finite part of the system tends asymptotically to statistical equilibrium, owing to the mechanical interaction with its surroundings. In particular, the velocity distribution of each particle and the distribution of distance between any two neighboring particles tend to the appropriate Gaussian equilibrium distributions; equipartition of kinetic and potential energy is demonstrated. This last result holds also under more general conditions. The limiting process involved in passing from the infinite to the finite system is considered, and it is shown that for a sufficiently short time the behavior of a finite system is the same as that of an infinite one.

From authors' summary by L. M. Grossman, USA

3335. Meixner, J., Thermodynamical theory of relaxation phenomena and its relation to aftereffects (in German), *Kolloid Z.* **134,** 1, 3–14, Dec. 1953.

The thermodynamical theory is developed for a limited number and an infinite number of internal mechanisms, on the basis of irreversible processes under different conditions, such as adiabatic or isotherm, isobaric or isochoric, etc. Relations between the different times of relaxation corresponding to these conditions are established in the form of differential equations. It is assumed that the deviations from thermodynamical equilibrium are so small that the equations are linear. Integrated dynamical equations of state thus derived are then postulated in a general theory of aftereffects. The presentation is formal.

M. Reiner, Israel

3336. Hall, N. A., and Ibele, W. E., The tabulation of imperfect-gas properties for air, nitrogen, and oxygen, ASME Ann. Meet., New York, Dec. 1953. Pap. 53—A-5, 16 pp.

Paper is a valuable addition to our knowledge of the properties of air, nitrogen, and oxygen. J. A. Beattie, USA

3337. Sato, M., Fujita, S., and Kajima, T., Lowering of freezing point of water enclosed in a cylindrical and spherical container (in German), *J. sci. Res. Inst. Tokyo,* **47,** 1–9, Dec. 1953.

In a container completely filled with water, authors first calculate the pressure set up during freezing as a problem in elasticity. The lowering of freezing point due to increase of pressure is then predicted by using Clausius-Clapeyron equation, the volume change and heat of fusion being assumed constant. Experimental checks are satisfactory. L. S. Dzung, Switzerland

3338. Mason, B. J., The spontaneous nucleation of supercooled water, *Proc. roy. Soc. Lond.* (*A*) **215,** 1120, 65–66, Nov. 1952.

3339. Waterhouse, F. M., Use of sorbents for drying process gas and air, ASME Ann. Meet., New York, Dec. 1953. Pap. 53—A-204, 11 pp.

Reduction of the temperature and humidity of process gas or air is normally effected with mechanical refrigeration and heat-exchange equipment. The vapor pressures of certain chemical sorbents render them capable of these control functions in certain cases. This paper reviews the theory of sorbent-controlled temperature and humidity, listing several available sorbents and indicating the criteria for selecting a control system involving sorbents. From author's summary

3340. Lype, E. F., Kinetic theory of evaporation rates of liquids, ASME Ann. Meet., New York, Dec. 1953. Pap. 53—A-134, 21 pp.

The anomalously low evaporation rate of water is explained on consideration of water as a "pseudo-crystalline" fluid. Volmer's model of crystal evaporation is applied which derives kinetic theory equations for evaporation and condensation based on the occurrence of "holes" in the surface. This model modifies the conventional evaporation concept for ordinary liquids where stripping of the surface in a regular manner is assumed to govern. The factor $e^{-u/kT}$ is introduced as the fraction of the surface covered by holes, where u is the average energy spent creating a hole. Mechanism of forming a cubical hole and the Virial theorem both indicate u to be of order of half the internal heat of vaporization.

Rate equations are applied to calculate heat-transfer coefficient in case of superheated liquid evaporating to form bubbles of saturated steam. Jacob gives $h = 1700$ kcal/m² hr deg C; calculation gives 16,000 for "hole" theory and 6.8×10^6 for conventional theory. Dergarabedian's observations of bubble growth in superheated water are also closely checked.

M. Gilbert, USA

3341. Ackermann, G., Decrease of loss due to incomplete expansion in connection with internal cooling in internal-combustion engines with injection (in German) *Motortech. Z.* **15,** 1, 3–11, Jan. 1954.

Author proposes a method whereby the loss incurred by incomplete expansion in internal-combustion engines is reduced. Paper is a detailed thermodynamical analysis of an engine cycle in which part of the suction air would be ejected through the exhaust port during the first part of the compression process. This would cool the valve and the cylinder walls while diluting the residual gases. This modified dual combustion cycle is analyzed using higher than usual constant specific heats and a specific heat ratio of 1.3.

Calculations and intuitive reasoning enable the author to claim reduction of incomplete expansion loss, reduction of fuel consumption, high compression ratios, high volumetric efficiency, and high thermal efficiency without appreciably lowering the mechanical efficiency.

No practical description of the proposed engine is given and no experimental data are cited. A. B. Cambel, USA

3342. Mott, N. F., Introductory remarks to a discussion on theory of liquids, *Proc. roy. Soc. Lond.* (*A*) **215,** 1120, 1–4, Nov. 1952.

A comparison is given between flow in liquids, creep in crystals, and intercrystalline slip. A further comparison is made between latent heats of fusion, shear moduli, and the energies to form vacancies. From author's summary

Heat and Mass Transfer

(See also Revs. 3086, 3106, 3208, 3285, 3290, 3291, 3293, 3340, 3341, 3423)

3343. Klemens, P. G., The specific heat and thermal conductivity of graphite, *Austral. J. Phys.* 6, 4, 405–409, Dec. 1953.

The specific heat of graphite is discussed in terms of a modified Debye treatment. It is shown that the contribution from the longitudinal waves varies as T^3 below 45 K and as T^2 at higher temperatures, whereas the usual two-dimensional treatment leads to a T^2 variation at all low temperatures. Similarly, the transverse contribution varies as T^3 at lowest temperatures, but above 10 K it varies as T^2.

The temperature variation of the thermal conductivity differs from the variation of the specific heat, even though the thermal resistance arises from boundary scattering. This is explained in terms of a mean free path for waves in the hexagonal plane, which is considerably larger for longitudinal than for transverse waves, resulting in an increased contribution of the former to the thermal conductivity.

This treatment has been confined to a rough estimate of the relevant parameters occurring in the simplified lattice theory of specific heat and thermal conductivity. In view of the lack of detailed knowledge of the interatomic forces and the uncertain experimental material, there is no point in refining these calculations. It does appear, however, that the thermal conductivity can be related to the specific heat according to the usual lattice theory, if account is taken of the special features arising from the high anisotropy of graphite. In order to verify this theory, it would be of value to have measurements of the specific heat from 2 to 8 K and of the thermal conductivity of a single crystal of graphite.

From author's summary and conclusion by J. Kestin, USA

3344. Berman, R., Simon, F. E., and Ziman, J. M., The thermal conductivity of diamond at low temperatures, *Proc. roy. Soc. Lond.* (*A*) **220,** 1141, 171–183, Nov. 1953.

3345. Collins, R. E., A new analogy in transient heat conduction, *Amer. J. Phys.* **21,** 7, 501–503, Oct. 1953.

A mathematical parallel is shown between the velocity of, and heat flow across, an isothermal surface and the classical group and phase velocities of wave theory. No attempt at utilizing this parallelism appears to have been made, possibly because it is rather highly idealized and thereby restricted.

F. C. Hooper, Canada

3346. Egerváry, J., and Lovass-Nagy, V., The solution of the heat conduction differential equation with boundary-value condition depending linearly on time (in French, with Hungarian and Russian summaries), *Magyar Tud. Akad. Alkalm. Mat. Int. Közl.* **1** (1952), 11–22, 1953.

The boundary-value problem solved in this paper is: $u_t = a^2\Delta u$, $u = 0$ when $t = 0$, $b\partial u/\partial n + u = vt$ on the boundary (b, v constants), and describes conduction of heat in a body which is being heated. The solution is written out explicitly for a rectangular finite slab, and some graphs and numerical values are also given.

Courtesy of Mathematical Reviews A. Erdélyi, USA

3347. Widder, D. V., Positive temperatures on a semi-infinite rod, *Trans. amer. math. Soc.* **75,** 510–525, 1953.

In title source **55,** 85–95, 1944, author proved that any solution $u(x\ t)$ of the heat equation, nonnegative for $0 < t < c$ and tending to zero as $t \downarrow 0$, is identically zero. Here the work is extended to the semi-infinite strip: a nonnegative solution of the heat equation in $0<t<c$, $0<x<\infty$, which tends to zero as (x, t) approaches the coordinate axes, is identically zero. The example $xt^{-3/2}\exp(-x^2/4t) = u(x, t)$ shows that approach has to be taken in the two-dimensional sense. Let $k(x, t) = (4\pi t)^{-1/2}\exp(-x^2/4t)$, let $p > 0$, let $\alpha(y)$ and $\beta(y)$ be monotone increasing functions such that ${}_{0+}\int^1 y^p d\alpha(y) < \infty$ and $\beta(y)$ is positive. Then for $0<t<c$, $0<x<\infty$

$$u_1(x, t) = pxt^{-1}k(x, t) + {}_{0+}\int^{\infty}[k(x - y, t) - k(x + y, t)]d\alpha(y)$$

$$u_2(x, t) = -{}_{0}\int^{t} k(x, t - y)d\beta(y)$$

are positive solutions of the heat equation, the former vanishing on the positive t-axis, the latter on the positive x-axis, and every positive solution with these initial properties is representable in such a manner. Finally, every solution which is positive in the semi-infinite strip is of the form $u_1(x, t) + u_2(x, t)$ where $u_1(x, t)$ and $u_2(x, t)$ have the representations given above.

Courtesy of Mathematical Reviews E. Hille, USA

3348. Benfield, A. E., The effect of accumulation on temperatures within a snowfield, *J. Glaciology* **2,** 14, 250–254, 1952.

The wave of cold temperature, which begins to propagate into a snow field during the winter, may be considerably enhanced by the thermal blanketing of snow accumulating on the surface. This effect is discussed theoretically by means of calculations based on the mathematical theory of the conduction of heat in solids. The results of these calculations show that, for an assumed steady velocity of accumulation at the rate of 4 meters/year or 8 meters/year, the winter cold wave should assume significantly larger proportions than in the absence of accumulation.

From author's summary

3349. Ostrach, S., Combined natural- and forced-convection laminar flow and heat transfer of fluids with and without heat sources in channels with linearly varying wall temperatures, *NACA TN* 3141, 74 pp., Apr. 1954.

Author extends the results of his earlier work by analyzing heat transfer under the conditions specified in the title. It is found that the product of the reciprocal of the ratio of specific heats and the Prandtl number and the modified Grashof number (modified Rayleigh number) as well as a parameter $K_A = PrGr_A\text{-}\beta f_x d/c_p$ is of significance, where f_x is the negative of the x-component of body force per unit mass and the other symbols have their conventional interpretation. Solutions of this problem are obtained in terms of universal functions of temperature and velocity. It is shown that when the ratio of CK_A (where C is related to the mass flow) to the Ra number is of unit order of magnitude, the effects of frictional heating can be appreciable. The results are compared with other approximate solutions and the range of validity of the latter is shown.

Y. S. Touloukian, USA

3350. Nusselt, W., Heat transfer, diffusion, and evaporation, *NACA TN* 1367, 36 pp., Mar. 1954. (Translation from *ZAMM* **10,** 2, 105–121, 1930.)

The general similarity of heat- and mass-transfer (diffusion) processes is discussed, with particular reference to the lack of complete identity of the relations governing the two phenomena. It is indicated that, for example, the boundary conditions in the two cases at the surface of a body will not be the same. The correct equation of diffusion is given for various simple cases. Generalized relations for combined heat and mass transfer are then evolved for particular situations, comparisons being made

among several different approaches to the problem. Finally, the effect of a buoyancy force field on the generalized relations is considered, with special reference to the evaporation of water.
From author's summary

3351. Aladyev, I. T., Experimental determination of local and mean coefficients of heat transfer for turbulent flow in pipes, *NACA TM* 1356, 18 pp., Feb. 1954 (translation from Russian).
See AMR 6, Rev. 2310.

3352. Hauger, H. H., Jr., Intermittent heating of airfoils for ice protection, utilizing hot air, *Trans. ASME* **76,** 2, 287–297, Feb. 1954.

An investigation into the fundamental transient heat-transfer characteristics of the airfoil leading-edge double-skin configuration, when heated intermittently by hot air for ice protection, was undertaken on an electrical analog computer. This problem is distinctive from other problems usually solved by such a computer in that an electric input circuit had to be designed which would account correctly for the heat balance as the air passes chordwise through the double-skin passages. Also, a combination of electrical networks was devised which would take into account satisfactorily the thermal resistance and capacitance of the growing layers of ice. This research reveals the effects on the de-icing ability of the double-skin design of variables deemed to be important in such a study. The feasibility of such an ice-protection system is attested, and the compromises inherent in the cyclic use of hot air are determined.
From author's summary by M. Tribus, USA

3353. Moeckel, W. E., Use of aerodynamic heating to provide thrust by vaporization of surface coolants, *NACA TN* 3140, 37 pp., Feb. 1954.

The possibility is investigated of providing propulsion by utilizing heat produced by friction on aircraft walls and at the same time maintaining aircraft structure at a sufficiently low temperature. Liquid and solid coolants are considered with vaporization temperature considerably below equilibrium surface temperature. The coolant is brought into contact with aircraft walls through a heat exchanger and thereby vaporized and heated. It is then collected, expanded through a nozzle, and ejected from the aircraft, thus providing thrust. Analysis is made for various coolants of specific impulse, thrust, requirements for heat exchanger, and other relevant quantities. Hydrogen vaporization as a sole means of propulsion is competitive with conventional rocket propulsion only at high Mach numbers; as auxiliary propulsion it provides a specific impulse comparable to that of conventional rocket propulsion. In both cases, more than adequate cooling of aircraft walls is provided.
H. Schuh, Sweden

3354. Orr, J. L., Milsum, J. H., and Rush, C. K., Electrothermal de-icing systems: Their design and control, *Nat. aero. Establ. Canad.* LR—70, 78 pp., Mar. 1953.

3355. Fettis, H. E., On a differential equation occurring in the theory of heat flow in boundary layers with Hartree's velocity profiles, *J. aero. Sci.* **21,** 2, 132–133, Feb. 1954.

In an earlier paper by H. Schuh [AMR 7, Rev. 2152], two differential equations were derived for temperature profiles associated with Hartree's velocity profiles for large values of Prandtl number and varying wall temperatures. For the second of these equations author obtained a solution in closed form with the help of Whittaker's form of the confluent hypergeometric function, and a simple expression is given for heat-transfer coefficient. Reviewer notes that a similar result for temperature profile was previously given by B. Punnis [*J. aero. Sci.* 20, 7, p. 505, 1953].
H. Schuh, Sweden

3356. Herbeck, M., Approximate solutions for heat transfer with convection flows, *J. aero. Sci.* **21,** 2, 142–144, Feb. 1954.

Solutions of the energy equation for certain incompressible low-speed laminar boundary-layer flow have been obtained by Lighthill, Schuh, and Punnis. These flows are characterized by certain stream function distributions. Author finds solutions with other but related stream function distributions; one of them corresponds to the separation flow. Results of this latter can be compared to results of numerical integration of Levy and good agreement obtained.
P. A. Libby, USA

3357. Scesa, S., and Levy, S., Heat transfer to constant-property laminar boundary-layer wedge flows with stepwise and arbitrary wall-temperature variation, *Trans. ASME* **76,** 2, 279–286, Feb. 1954.

Using an exponential expression for the velocity profile [see AMR 5, Rev. 2440] and assuming that the temperature profile is expressible by a formula of the same type, an approximate method is obtained for solving the boundary-layer equations of motion and temperature, with dissipation neglected. The method can be applied to a gas of any Prandtl number. Specific results are calculated for Prandtl numbers of 0.7 and 1.0 for five wedge angles. The heat transfer is compared with previous analyses that used a linear velocity profile and also with one case, for constant wall temperature, calculated from an exact solution. The agreement with the exact solution is good.
N. Tetervin, USA

3358. Danese, G., On the law of temperature variation in cylindrical walls (in Italian), *Termotecnica* **7,** 6, 231–232, June 1953.

Author considers the elementary problem of determining the steady temperature in a solid bounded by cylindrical surfaces, when the conductivity of the medium is a linear function of the temperature.
G. Sestini, Italy

3359. Fraser, D., Note on the flight testing and assessment of icing protection systems, *Nat. aero. Establ. Canad.*, LR—50, 9 pp., Mar. 1953.

3360. El Wakil, M. M., Uyehara, O. A., and Myers, P. S., A theoretical investigation of the heating-up period of injected fuel droplets vaporizing in air, *NACA TN* 3179, 83 pp., May 1954.

Calculations were conducted in nonequilibrium stage beginning at the time single droplets come into contact with air and up to point at which they reach equilibrium or wet-bulb temperatures, at which time all heat transferred from air to droplet is carried away by diffusing vapor. After this point is reached, heat and mass transferred to and away from droplet become functions only of radius and velocity of droplet. Results are presented as temperature-time, mass-time, and penetration-time histories, as well as heat- and mass-transfer histories of single droplets.

Calculations show unsteady-state portion of total vaporization time to be of importance in most cases. At high air temperatures and for high-volatility fuels, unsteady state represented greater part of the vaporization time. Larger droplets would be expected to reach combustion zone while still in unsteady state.

Calculated curves depend upon use of heat- and mass-transfer correlations that are extended far beyond conditions under which they were obtained. Thus, extensive use of values shown

on the calculated curves should not be made until either curves or extrapolations of heat- and mass-transfer correlations have been checked experimentally.

Apparatus was set up to obtain experimental temperature-time histories of comparatively large droplets vaporizing in air streams at constant velocities and atmospheric pressure. This apparatus is described and a few experimental curves are included. These curves show the relative distribution of the time interval between unsteady and steady states when different air temperatures and different fuels are used.

E. Giffen, England

3361. Forster, H. K., and Zuber, N., Growth of a vapor bubble in a superheated liquid, *J. appl. Phys.* **25**, 4, 474–478, Apr. 1954.

The integrodifferential equation for the growth of a vapor bubble in a superheated liquid is formulated and discussed. An integral equation is formulated and solved for the region in which the inertia of the surrounding liquid is unimportant in its effect on the growth rate of the bubble. This includes the entire visible range for bubbles at the usual degrees of superheat. The experimental verification is excellent. Reviewer finds the result as good as that of Plesset and Zwick, who solved the same problem (see following review), and the mathematical steps are much easier to follow. P. Griffith, USA

3362. Plesset, M. S., and Zwick, S. A., The growth of vapor bubbles in superheated liquids, *J. appl. Phys.* **25**, 4, 493–500, Apr. 1954.

The growth of a vapor bubble is controlled by three factors: the inertia of the liquid, the surface tension, and the vapor pressure. Taking into consideration these three factors, a solution for the radius of the vapor bubble as a function of time is obtained which is valid for bubbles in the visible range for the common degrees of superheat. Comparison with experimental observations is excellent. Reviewer finds close agreement with the work of Forster and Zuber, with a different mathematical approach to the problem. P. Griffith, USA

3363. Coles, W. D., and Ruggeri, R. S., Experimental investigation of sublimation of ice at subsonic and supersonic speeds and its relation to heat transfer, *NACA TN* 3104, 29 pp., Mar. 1954.

A neat set of experiments is used to show that (1) the roughness of typical ice formations on aircraft increases the heat and mass transfer by 40 to 50% over predicted (smooth surface) rates; (2) even at Mach numbers of 1.3 the methods of analysis used in subsonic flow are valid; and (3) the conclusion of Messinger [AMR **6**, Rev. 2916] that sublimation rates will be too low to afford protection to high-speed airplanes is supported. Authors introduce a clever method of getting surface temperature, i.e., raising free-stream dew point until condensation occurs. Reviewer believes major shortcoming of report is that representative raw data are not given to permit others to attempt to draw further conclusions or to guide others who may wish to extend or repeat the experiments. M. Tribus, USA

3364. Best, A. C., Dimensionless equations for the growth of a drop of salt solution, *Quart. J. roy. meteor. Soc.* **80**, 343, 89–93, Jan. 1954.

The usual equations for the transfer of heat and water vapor to and from a drop of salt solution in an atmosphere with which the drop is not in equilibrium involve the relative humidity of the atmosphere, the drop size, the mass of the salt nucleus, and various physical characteristics of air and water which depend upon temperature. Generally, an explicit solution of the equations is not possible, and if more than one set of circumstances is to be considered, considerable labor may be involved in obtaining numerical solutions. Paper indicates a convenient way of manipulating the equations so that the effects of different temperatures and different salt-nucleus masses may be allowed for by means of a simple multiplying factor.

From author's summary

3365. Geneve, L. F. C. A., The transmission of low-pressure steam for process heating, *Instn. mech. Engrs. Proc.* (*A*) **167**, 4, 394–398, 1953.

This paper shows how, in the case of steam transmitted entirely for use in process heaters, it is the total heat energy that finally counts; and hence a pipeline can be designed for a high pressure drop and a high velocity of flow, since the friction work and the kinetic energy will be reconverted into heat which is also available at the outlet of the pipeline. The size and cost of the piping and lagging can, therefore, be kept low, and radiation losses will also be reduced.

In a long transmission, however, the very rapid increase of velocity toward the end of the pipeline may cause the steam velocity to reach the "acoustic" value; and when this occurs, a "choking" effect results in the discharge being lower than the expected value. The method of design proposed is to calculate the size of pipe required so that the given length of pipeline is an assumed fraction, say, 0.80 to 0.90 of this "choking" length. This insures that the required discharge will be obtained with the minimum size of pipe and with no danger of "choking."

Simple formulas are derived with the help of the approximate Callendar expression for total heat, which is applicable with reasonable accuracy at low pressures, and a case is worked out for a combined power-and-process steam installation, which shows that the problem may have several solutions of equal heat-utilization efficiency. From author's summary

3366. Judd, J. H., Transient temperatures in heat exchangers for supersonic blowdown tunnels, *NACA TN* 3078, 35 pp., Apr. 1954.

This paper deals with the analysis of heat exchangers of the heat-accumulator type, which are widely used in the design of supersonic wind tunnels.

The temperatures of the solid and of the fluid are determined as a function of the time and of a space coordinate measured along the axis of the heat exchanger. Following hypotheses are used: Heat is transferred according to Newton's law of heat convection; any transfer of heat along the axis of the heat exchanger is neglected; the physical parameters of both the solid and the fluid are constant in a cross section of the heat exchanger; the density of the fluid and the heat-transfer coefficient are assumed constant. The solid is supposed to be initially at constant temperature everywhere.

As far as the fluid is concerned, three types of boundary conditions at the inlet section of the heat regenerator are considered: One in which the fluid temperature is constant (such a case was first treated by Schumann and subsequently by Furnas); another in which the temperature decreases exponentially with the time; and a third in which the temperature of the fluid decreases linearly with the time.

Experiments have been carried out and have shown good agreement with the results of the paper.

In the reviewer's opinion, paper is of interest in the design of equipment for wind tunnels. The case in which the temperature of the fluid decreases linearly with the time has a particularly practical importance. A. Miele, USA

3367. Veron, M., and Treves, F., Heat exchanger surrounded by an isothermal wall (in French), *C. R. Acad. Sci. Paris* **238,** 3, 329–331, Jan. 1954.

Two fluid streams at counterflow exchange heat with each other and with a common isothermal wall. Expressions of temperatures show either a maximum point or a point of inflection. This property is utilized for certain industrial processes to keep a fluid stream at nearly the same temperature for a long time.

L. S. Dzung, Switzerland

3368. Schrage, R. W., A theoretical study of interphase mass transfer, New York, Columbia Univ. Press, 1953, viii + 103 pp. $3.50.

This study is an attempt to derive, by the methods of the kinetic theory, the rates of evaporation and condensation at the surface of a liquid or solid phase from the thermodynamic properties of the gas phase alone. The approach to this problem consists in the assumption of a vapor interface of temperature T_0 separating the condensed phase with surface temperature T_s from the gas phase with temperature T_1. The author intends to calculate the mass transfer into the interface from the adjacent bulk phases under nonequilibrium conditions in order to obtain the net rates of evaporation and condensation. The execution of this interesting idea is, unfortunately, beset by a disregard for accepted procedure in kinetic theory which makes most of the author's findings meaningless or erroneous and severely limits the value of this treatise. Its principal accomplishment lies in suggesting a new approach which may inspire other workers to further research along these lines.

After a critical discussion of the literature on interphase mass transfer, author starts to calculate the number of molecules, w_{s+}, streaming from the surface of the condensed phase (p. 27). This is done without reference to the distribution function of the molecules in the surface layer which controls the properties of the molecules streaming from the surface. In its place, a distribution function for the hypothetical interface vapor is introduced with molecules in free translatory motion. This procedure is used throughout the book and makes all calculations involving the emitted molecules meaningless. The author's concept of an interphase mass transfer, controlled solely by the properties of the gas phase and entirely independent of the properties of the liquid phase—which are nowhere mentioned—seems to this reviewer untenable and contrary to experience. Next, the author introduces the concept of "absolute rate of vaporization" as the total flow from the surface $\times$ the condensation coefficient σ. Unfortunately, the author does not recognize the validity of the experimental evidence for values $\sigma < 1$, and confines his study to systems with $\sigma = 1$, thus depriving himself of the golden opportunity of gaining insight into an important phenomenon affecting the interphase mass transfer.

Two different methods are presented to calculate the number of gas molecules w_{0-} striking the interface at nonequilibrium; the first one is based on the idea that, for mass transfer to occur, there must exist in the gas phase a mass flow velocity U_0 normal to the interface. Accordingly, the distribution function for a gas with mass flow is used in the derivation of the number of molecules striking the surface. An error is made in the step leading from 3.1–1 to 3.1–2, but 3.1–9 is accidentally correct due to the fact that the values of ${}_0\int^\infty xe^{-x^2}dx$ and ${}_0\int^\infty x^3e^{-x^2}dx$ are identical. This same error is repeated throughout the treatise and does not cancel out when the author calculates the kinetic energy of the molecules. No theoretical determination for the fictitious velocity U_0 is given; instead, only a relation between U_0 and the net interphase mass transfer w is given in 3.1–15a

$$U_0 = (RT_0/2\pi)^{1/2}\,(w/w_{s+})$$

defining one unknown quantity by another unknown quantity.

The second method consists in assuming a distribution function for the gas molecules arriving at the interface, calculating from it the number of gas molecules striking the interface and balancing it against the number of molecules emitted from the condensed phase to obtain the net flow for nonequilibrium. No justification is given for arbitrarily assuming this distribution function, which is already entirely fixed by prescribing a distribution function for the gas phase. Thus, this calculation of mass transfer starts out with using for each phase a distribution function which does not comply with the physical requirements. In the progress of this calculation the above-mentioned error is retained, which becomes evident when the average kinetic energy ϵ of a molecule in the interface is calculated: It follows from (5.4–7), (5.4–8), (5.4–26)

$$\epsilon = (E/w) = (5/2)kT$$

(k Boltzmann constant), while the correct value is $\epsilon = 2kT$ under the conditions used by the author. The same error also enters into the momentum equations. An empirical constant B in the assumed distribution function is left undetermined; instead, a relation between B and the mass transfer is given (5.4–8)

$$B = (2/\pi RT_s)^{1/2}\,(w/w_{s+})$$

again expressing one unknown quantity by another. Thus, neither of the two methods permits to obtain the mass transfer in terms of known physical properties.

The results obtained from this procedure are amazing. At nonequilibrium, interphase mass transfer is found to occur only when the gas temperature is less than the surface temperature of the condensed phase (p. 66); since condensation occurs in the direction from higher to lower temperature, the interface temperature for condensation must be higher than the temperature of the liquid surface; according to the author's findings, the interface temperature would then also be higher than the gas-phase temperature. Between liquid and gas would then be an interface with a temperature higher than both adjacent phases.

It is not surprising that the author was unable to find any experimental evidence in support of his theory.

E. F. Lype, USA

3369. Carman, P. C., and Haul, R. A. W., Measurement of diffusion coefficients, *Proc. Roy. Soc. Lond.* (*A*) **222,** 1148, 109–118, Feb. 1954.

For the purpose of studying diffusion in solids, in particular in fibers or granulated material, it may be convenient to observe the rate of absorption (or adsorption) by the solid of a pure gas or a component of a gaseous or liquid mixture. In this paper formulas, tables, and graphs are provided and new solutions of the diffusion equation are obtained by means of which diffusion coefficients are deduced from the rate of absorption. Mathematical results are illustrated by experimental data referring to the adsorption of butane on silica. R. Eisenschitz, England

3370. Spalding, D. B., Mass transfer in laminar flow, *Proc. roy. Soc. Lond.* (*A*) **221,** 1144, 78–99, Jan. 1954.

Expressions are derived for rate of mass transfer from (a) a flat plate in a longitudinal fluid stream, (b) a vertical flat plate by natural convection, and (c) the forward stagnation point of a sphere in a fluid stream. Calculations made by the von Kármán-Pohlhausen-Kroujiline method for Prandtl-Schmidt numbers of 0.71 are shown to be valid for all mass-transfer processes, but especially so for the combustion of liquid fuels. It is also shown that the stagnant-film theory leads to an overestimate of the mass-transfer rate of up to 30%. J. M. DallaValle, USA

3371. **Holleran, E. M., Diffusion and thermal diffusion of isotopic gases,** *J. chem. Phys.* **21,** 12, 2184–2187, Dec. 1953.

It is shown that, for argon and neon isotopes, the temperature variations of the thermal diffusion ratio and the diffusion coefficient can be calculated from each other. The results agree well with available diffusion data. P. Kriezis, Greece

3372. **Winterling, K. H., Dynamic adjustment of instruments that measure temperature by electrical methods** (in German), *ATM* no. 219, 73–76, Apr. 1954.

An analysis is made of the dynamic characteristics of the temperature-sensitive element and the measuring apparatus. The selection of time constants to give the minimum measurement errors is discussed. The applications where this type of adjustment is very important are pointed out.

W. L. Sibbitt, USA

3373. **Wesely, K. H., Automatic control in steam boiler plants** (in German), *Brennstoff-Wärme-Kraft* **6,** 1, 1–6, Jan. 1954.

The important requirements for automatic control of an up-to-date steam boiler plant are shown. The important control circles are shown and author describes how automatic control fulfills the requirements. From author's summary

Combustion

(See also Revs. 3153, 3274, 3322, 3360)

3374. **Wood, H. L., and Charvonia, D. A., The ignition of fuel droplets descending through an oxidizing atmosphere,** *Jet Propulsion* **24,** 3, 162–165, May–June 1954.

Ignition studies with three organic fuels, triethylamine, allylamine, and cyclohexene, as they descend in single droplets through the decomposition vapors of white fuming nitric acid are discussed. The pertinent parameters varied were acid-vapor temperature (350 C to 550 C), fuel temperature (10 C to 70 C), and fuel-drop diameter (2.6 mm to 4.2 mm). Theoretical approaches to explain the observed ignition delays have not been successful.

From authors' summary

3375. **Shafer, M. R., and Bovey, H. L., Applications of dimensional analysis to spray-nozzle performance data,** *J. Res. nat. Bur. Stands.* **52,** 3, 141–147, Mar. 1954.

Applications of dimensional analysis to performance of continuous fuel spray nozzles of the centrifugal type. Equations show the relations between nozzle capacity, nozzle dimensions, mean drop diameter, spray angle, fuel pressure, and the density, viscosity, and surface tension of fuel. Using experimental data available at the National Bureau of Standards and in the literature, good correlation has been found as to nozzle capacity and a fair correlation as to mean drop diameter and spray angle. The theoretical investigation is based on the application of Buckingham's pi- theorem to the flow rates of the simplex and duplex types of nozzle and to the mean drop size and angle of the spray. Author states that the curves given apply only to the particular nozzles investigated and have no general validity. The method, however, promises economy in analyzing, correlating, and interpreting experimental data from a limited number of experiments, and predicting differences in performance due to the use of liquids having different physical properties.

From authors' summary by K. J. De Juhasz, Germany

3376. **Barr, J., Length of cylindrical laminar diffusion flames,** *Fuel* **33,** 1, 51–59, Jan. 1954.

A new theory giving the length of open diffusion flames is presented which makes some allowance for momentum transfer between fuel and air streams. The results of this theory are compared with previous theories of Hottel, et al. and Wohl, et al., and with published experimental data for butane and city gas. Open flame lengths predicted by all three theories agree fairly well with the experimental data, but the treatment of Barr serves to show up the significant difference in the velocity distributions in open and enclosed diffusion-flame systems.

Measurements of the length of enclosed butane-air diffusion flames are presented and discussed. Changes in inner-tube eccentricity, air-flow rate, fuel-flow rate, inner-tube diameter, and inner-tube thickness were all found to have some effect upon the flame length of such enclosed flames, but it was the fuel-flow rate that had the greatest influence of all these variables. A diagram plotted on the basis log (*butane flow rate*) vs. log (*air flow rate*) is given that shows the "regions" in which different types of enclosed cylindrical diffusion flame are formed. The author has given special names to several of the novel flame types that he discovered, e.g., a convective flame, meniscus flame, vortex flame.

Reviewer believes that this paper is valuable both for the new data presented and as an authoritative assessment of the present status of the subject, which has important chemical engineering applications, e.g., open-hearth furnace design. In this connection, it would be valuable to compare (and contrast) the present laboratory results with those obtained with industrial flames. B. P. Mullins, England

3377. **Cardwell, F. D., A direct method for flame temperature calculation—partial oxidation of methane,** ASME Ann. Meet., New York, Dec. 1953. Pap. 53—A-203, 7 pp.

Paper illustrates the development of a simple formula for the direct calculation of the theoretical flame temperature that results when methane is burned with a deficiency of air, producing a flue gas which is rich in carbon monoxide and hydrogen. This gas is known as a reducing gas or atmosphere and has many uses, including those of a reformed gas. Preheated oxygen and steam may be added to the burner gases which also may be preheated to some desired temperature before combustion takes place. Provision is made in the formulation to include any combination of the foregoing, which is known as the burner-gas analysis.

From author's summary

3378. **Fristrom, R. M., Avery, W. H., Prescott, R., and Mattuck, A., Flame zone studies by the particle track technique. I. Apparatus and technique,** *J. chem. Phys.* **22,** 1, 106–109, Jan. 1954.

Flame temperature profiles of laminar premixed Bunsen flames are obtained by using flame gases themselves as a gas thermometer. These data are needed to understand combustion and flame-spreading phenomena.

Magnesium oxide particles (average size, less than 4 microns) are introduced into the burner stream. Particles on a diametral cross section are photographed by stroboscopic illumination from the side with electronic flash lamps controlled by a ballistic switch. Sources of error are discussed. The temperature profile is believed to describe translational temperatures; accuracy is believed to be within a few per cent, depending upon the pressure. Profile for propane-air flame front at $^1/_4$ atmosphere is shown.

Reviewer believes that Eq. 2 on page 107 should read: $T_i = T_0[v_i/v_0]\,[r_i/r_0]\,[M_i/M_0]$. E. E. Frost, USA

3379. **Everett, A. J., and Minkoff, G. J., High-speed photography of spark ignited, low pressure explosions of hydrogen-oxygen and methane-oxygen mixtures,** *Fuel* **33,** 1, 66–78, Jan. 1954.

3380. Heidmann, M. F., and Priem, R. J., Application of an electro-optical two-color pyrometer to measurement of flame temperature for liquid oxygen-hydrocarbon propellant combination, *NACA TN* 3033, 39 pp., Oct. 1953.

The development and application of an electro-optical two-color pyrometer for the measurement of temperature and emissivity in the exhaust gases from an open-tube combustor using liquid oxygen and a hydrocarbon fuel are described. Measurements were made during both normal and oscillatory combustion. Temperature variations up to 1000° R and emissivity variations of 10 to 1 were found to occur during combustor operation; the variations were sporadic and periodic during normal and oscillatory operation, respectively. Periodic variations at a frequency of 1000 cps were predominant; however, smaller amplitude oscillations at higher frequencies were also present. Satisfactory correlation was obtained between temperatures measured simultaneously by the two-color method and by a microwave absorption technique. Agreement between temperature and sound intensity change was also found to exist. During many combustion experiments, radiation intensity varied inversely with temperature and directly with emissivity, indicating a need for caution in the interpretation of combustion photographs on the basis of light intensity. From authors' summary

3381. Predvoditelev, A. S., Results of the scientific technical conference on problems concerning the theory of the combustion of fuel (in Russian), *Izv. Akad. Nauk SSSR Otd. tekh. Nauk* no. 5, 741–751, May 1953.

3382. Knorre, G. F., Application of the modern theory of combustion to an efficient survey of furnace processes (in Russian), *Izv. Akad. Nauk SSSR Otd. tekh. Nauk* no. 5, 730–735, May 1953.

3383. Semenov, N. N., Basic problems of a modern theory of homogeneous combustion of uniform gas systems (in Russian), *Izv. Akad. Nauk SSSR Otd. tekh. Nauk* no. 5, 708–729, May 1953.

3384. Blinov, V. I., Combustion of coal in a zone of low temperatures (in Russian), *Izv. Akad. Nauk SSSR Otd. tekh. Nauk* no. 5, 736–740, May 1953.

Paper is an addition to the earlier published facts that the combustion of the coal at low temperature occurs not only on the outside surfaces but also on the inside walls of the pores of the sample. Author attempts to clarify the different activity of various types of coal, particularly in regard to their porosity. Study of the combustion process is carried out on a sample of spherical shape. Analytical treatment of the problem assumes cylindrical or conical pores arranged perpendicularly to the sphere surface. Expressions for specific velocity of combustion for region of low and high temperatures are derived. The computed values are compared with the test data and found to be in close agreement. It is shown that the energy of activation has a maximum value for electrode coal and is approximately twice higher than the value for Moscowvian coal. Reaction between carbon and oxygen depends upon the concentration of oxygen along the pores. This concentration decreases considerably with the distance from burning surface, especially with increasing temperatures; therefore, the retardation of the process will occur at lower temperature for coal with fine pores than for the coal with large pores. D. Kurtovich, USA

3385. Predvoditelev, A. S., Status of the theory of homogeneous and heterogeneous combustion (in Russian), *Izv. Akad. Nauk SSSR Otd. tekh. Nauk* no. 5, 705–707, May 1953.

3386. Guerin, H., The problem of fuel reactivity. How it can be solved (in French), *Chim. et Industr.* **70,** 5, 875–885, Nov. 1953.

After explaining the notion of fuel reactivity, author shows how, resting on kinetics work, one can hope to determine absolute reactivities in the laboratory. He insists that the reactivities of fuels vary during the course of their utilization so that it is not possible to deduce a practical reactivity from a laboratory test. As it is impossible to reproduce in a laboratory all the conditions of industrial use, it is necessary, during a laboratory test, to carry out practical well-defined checks on well-studied fuels. Up to now this has rarely been realized. P. Laffitte, France

3387. Beeton, A. B. P., The calculated performance of ethyl alcohol-water mixtures as rocket fuels with liquid oxygen, *Aero. Res. Counc. Lond. Rep. Mem.* 2816, 8 pp., Mar. 1948, published 1953.

Specific impulses and combustion temperatures have been calculated for rocket propellants consisting of liquid oxygen and ethyl alcohol-water mixtures. This system appears to have a number of advantages compared with the corresponding liquid oxygen and petrol system. From author's summary

3388. Lang, M., Steam superheating, CO_2-content, and change from coal- to oil-firing (in German), *Brennstoff-Wärme-Kraft* **6,** 2, 51–53, Feb. 1954.

Change of fuel from coal to oil brings a decrease in volume and velocity of flue gas, whose influence on heat transfer may be well balanced by its increased CO_2-content so that the amount of steam generated will be increased. In a boiler furnace, however, this causes the lowering of flue-gas temperature and consequently that of the superheated steam. Increase by 1% of CO_2 in flue gas introduces a drop of 15 C in steam temperature. Author illustrates these relations with examples.

M. Kunugi, Japan

3389. Pulsating combustion and its application to steam raising, *Engng. Boiler House Rev.* **69,** 1, 2; 4–7, 35–38, Jan., Feb. 1954.

Condensed from a paper by F. H. Regust in *Mitt. der Vereinigung der Grosskesselbesitzer* no. 24, 419–436, June 1953.

3390. Truman, J. C., Some properties of intense sound waves in relation to combustion, *J. aero. Sci.* **21,** 1, p. 69, Jan. 1954.

3391. Truman, J. C., and Lipstein, N. J., A note on organ-pipe resonance in ducted burners, *J. aero. Sci.* **20,** 12, 846–847, Dec. 1953.

Authors compute effect of axial velocity of the gas on natural frequencies of a duct, using the wave equation with steady-state velocity component. Resonant frequency is reduced by $(1 - M^2)$ for subsonic flow, where M is Mach number. Authors suggest a further decrease, not calculated, owing to increase in end correction with increase in velocity. W. R. Dennis, USA

3392. Marsh, B. W., and Sears, G. A., Introduction to the analysis of supersonic ramjet power plants, *Jet Propulsion* 24, 3, 155–161, May–June 1954.

Analysis of ramjet performance is reviewed and charts are presented for the calculation of thrust coefficients from data specifying duct geometry and operating régime.

J. V. Foa, USA

3393. **Guenoche, H., and Jouy, M., Changes in the shape of flames propagating in tubes,** Fourth Symp. (International) on Combustion, 403–407, 1953; Baltimore, Md., Williams & Wilkins.

In order to obtain uniform propagation of the flame front, the openings at the initial and final ends of long cylinders were varied according to the nature of the mixture. Either end could be partially or completely closed. The cylinders after being evacuated were filled with a mixture of acetylene and air. Ignition was made at one end by means of a spark or flame. Photographs were made of the flame front as it propagated down the tube. Various flame shapes were obtained, depending on inlet and outlet openings, composition of mixture, and cylinder diameter. With uniform propagation, the flame tends to retain its initial shape over the entire course. With vibratory propagation, the flame surface undergoes change, the resonant frequency being a function of the length and character of the tube (open or closed end). With a tube open at both ends, two propagation patterns may appear. In all cases, the shape and area of the flame depend on the vibratory system. Paper discusses development of multicellular structure in regions of vibratory disturbance.

Burning velocities and propagation velocities are not given but can be estimated qualitatively from photographs.

D. Aronson, USA

3394. **Hottel, H. C., and Person, R. A., Heterogeneous combustion of gases in a vortex system,** Fourth Symp. (International) on Combustion, 781–788, 1953; Baltimore, Md., Williams & Wilkins.

Experiments were made with a vertical 6-in. diam cylinder into which air was admitted horizontally at the outer radius of the base through a ring of tangentially inclined vanes $1^1/_2$ in. high. Fuel gas (propane) entered vertically along the axis from below through a 2-in. diam pipe. Arrangements were made for removing the products from the top through a circumferentially disposed port followed immediately by a quenching water spray. In cold runs it was found that, with large entering tangential-radial velocity ratios, the static pressures could be correlated in terms of the dynamic head of the inlet tangential velocity and were a weak function of Reynolds number. The vortex had a central core rotating as a solid body which occupied 80% of the chamber volume. No downward circulation was observed in the central core except when the chamber discharged into free surroundings; in the latter case, the influence of the recirculation appeared to be slight. Over a twofold range of velocity, the only factors affecting the combustion efficiency were cylinder height and air-fuel ratio. Combustion occurred in a cylindrical annulus between the central core and the outer air stream with gas-air interfacial area substantially uninfluenced by operating variables. It is concluded that the absence of substantial recirculation in the core does not permit close comparison between the results from this apparatus and many gas-turbine combustion chambers.

W. R. Hawthorne, England

3395. **Wohlenberg, W. J., Minimum depth of the flame front for stable combustion and maximum time mean energy release rates over an interval of combustion progress for second-order reactions in a gaseous system at constant pressure,** Fourth Symp. (International) on Combustion, 796–806, 1953; Baltimore, Md., Williams & Wilkins.

Orders of magnitude of flame thickness and average heat-release rate are obtained for homogeneous mixture. Effect of value of energy of activation assumed is shown to be large, and this perhaps justifies admittedly crude analytical treatment. Curves are given for *n*-dodecane, showing effect of choice of energy of activation and excess air.

W. R. Hawthorne, England

3396. **Richardson, J. M., Howard, H. C., Jr., and Smith, R. W., Jr., The relation between sampling-tube measurements and concentration fluctuations in a turbulent gas jet,** Fourth Symp. (International) on Combustion, 814–817, 1953; Baltimore, Md., Williams & Wilkins.

A sample of gas drawn from a turbulent flame through a chilled sampling tube, which may be presumed to quench chemical reaction, can contain both unreacted oxygen and fuel. By assuming a Gaussian variation of concentration with time at the sampling point, previous authors have derived a method of estimating the mean square of the local concentration fluctuations from the analysis of the sample. This paper redefines the mathematical problem and, by assuming a more general distribution function, obtains solutions which are more satisfactory than the earlier ones based on the Gaussian distribution, which the authors show is restricted to the case when mixing is good.

W. R. Hawthorne, England

3397. **Sawai, I., Kunugi, M., and Jinno, H., Turbulent diffusion flames,** Fourth Symp. (International) on Combustion, 806–814, 1953; Baltimore, Md., Williams & Wilkins.

First part describes experiments on mixing and burning of gas and air in rectangular two-dimensional furnace with gas and air ports occupying various portions of bottom wall. Results are correlated by theory which assumes turbulent mixing, with eddy diffusivity proportional only to velocity and scale of apparatus. Second part describes experiments on model of glass tank furnace using dilute solutions of alkali and acid to represent gas and air, the alkali stream being colored by phenolphthalein. Flame length is measured visually by disappearance of indicator. Discussion of effect of absence of volume change during model combustion is included. Since flame lengths are found to vary only slightly with entering velocity, reviewer believes that this effect may not always invalidate this promising model technique.

W. R. Hawthorne, England

3398. **Yamazaki, K., and Iinuma, K., Augmented flames in an engine combustion chamber,** Fourth Symp. (International) on Combustion, 914–918, 1953; Baltimore, Md., Williams & Wilkins.

Tests were made to determine the effect of induced turbulence on burning velocity and on knock in CFR engines. Turbulence was induced by a baffle plate, either solid or with nozzles or slits mounted in the piston crown. Burning velocity was determined by the time required for flame to move from ignition plug to ionization gap on opposite side of combustion chamber.

Results showed baffle plates increased burning velocity up to 35%, the effect being smaller the greater the burning velocity. Indicator diagrams showed knocking is suppressed by baffles. This is attributed to the increased burning velocity.

Marjorie W. Evans, USA

Acoustics

(See also Revs. 3103, 3223, 3224, 3390, 3391)

3399. **Richards, E. J., Jet engine noise,** *J. roy. aero. Soc.* **58**, 520, 221–223, Apr. 1954.

An introduction to the jet-engine noise problem is given, along with a discussion of the sources of the noise. Brief mention is made of various noise-suppression devices that have been successfully used on model jets.

H. H. Hubbard, USA

3400. Greatrex, F. B., Engine noise, *J. roy. aero. Soc.* **58,** 520, 223–235, Apr. 1954.

Results of a detailed survey of the noise field of a Derwent engine are shown, along with some noise data from three other jet engines. These results are in general agreement with published data on model jets and confirm some aspects of the Lighthill theory. Of special interest is an evaluation of the effects of "teeth" (attached to the nozzle exit) on the noise from a jet engine. These "teeth" generally reduced the noise at the lower frequencies and increased the noise at the higher frequencies, while keeping the total acoustic energy about constant. The author states that the resultant changes in the noise spectrum will be beneficial in alleviating the ground runup and cabin-noise problems of jet aircraft. H. H. Hubbard, USA

3401. Lilley, G. M., Aerodynamic noise, *J. roy. aero. Soc.* **58,** 520, 235–239, Apr. 1954.

A discussion is given of the various sources of aerodynamic noise, such as propellers, boundary layers, and jets. Lighthill's theory of aerodynamic noise generation is also summarized and discussed briefly. Some detailed surveys of the noise fields of cold air jets are shown for both the choked and unchoked conditions. These data are interpreted as further evidence that the high-frequency noise originates near the nozzle of the jet, whereas the low frequencies originate further downstream.

H. H. Hubbard, USA

3402. Warren, C. H. E., Noise associated with supersonic flight, *J. roy. aero. Soc.* **58,** 520, 239–245, Apr. 1954.

A general discussion is given on the noise due to sonic bangs. These are noted to be associated with sonic or supersonic flight and are primarily due to the shock formations on the airplane. A bang is experienced from each occasion on which the aircraft is flying such that its component of velocity in the observer's direction is sonic. From normal supersonic flying at high altitude, the order of magnitude of the sonic bang would be about 1 lb/ft^2 or 130 db. It can be anticipated that for low-level supersonic flight the pressures would approach the wing loading of the aircraft. Very little can be done in the design of the aircraft to reduce the noise due to sonic bangs; thus control of this source of noise will have to come from control over supersonic flying.

H. H. Hubbard, USA

3403. Fleming, N., Measurement of noise on the ground from aircraft in flight, *J. roy. aero. Soc.* **58,** 520, 245–248, Apr. 1954.

A description is given of some techniques which have been used for measuring noise on the ground from aircraft in flight. Some examples of noise measurements for a helicopter as well as propeller and jet airplanes are included. Time-history records of the noise from a single-engined helicopter passing overhead at various altitudes are shown as well as some data for a given reciprocating engine with different exhaust and propeller configurations for comparison. Data are also presented for a Comet airplane which indicate that, as the aircraft passes overhead on takeoff, a ground observer will not particularly notice the noise of the impeller, whereas in landing this may be a major noise source. In either case, the low-frequency noise from the jets is most evident after the aircraft is an appreciable distance past the observer. H. H. Hubbard, USA

3404. Hayhurst, J. D., Ground-to-ground noise, *J. roy. aero. Soc.* **58,** 520, 248–254, Apr. 1954.

Paper provides an insight into the nature of the problem of reduction of noise due to the ground operation of aircraft. Directional characteristics of the noise from airplanes are discussed briefly, as is the noise reduction due to atmospheric and terrain losses for propagation over large distances. Running-up pens are considered to be practical for noise reductions of up to 25 phons and are particularly attractive because of their adaptability to all types of aircraft. For jet aircraft, ground muffling may be useful, particularly if very large noise reductions are required. For propeller airplanes, ground muffling does not appear to be satisfactory since the exhaust is not the only major noise source.

H. H. Hubbard, USA

3405. Powell, A., The reduction of choked jet noise, *Proc. phys. Soc. Lond.* (*B*) **67,** part 4, 412B, 313–327, Apr. 1954.

Some methods of reducing that noise peculiar to choked jets are investigated. The methods used consist of the notching of the exit edge of the jet nozzle, the introduction of cambered radial vanes, and ventilation of the nozzle by means of a gauze extension. The magnitude of the noise of a jet emanating from a plain exit is shown to be susceptible to the state of the exit edge and the reflecting area presented by the nozzle body in the plane of the exit. It is suggested that the presence of initial turbulence or noise will also tend to reduce the magnitude of the sound, and this effect may be of importance in the practical case of the jets of propulsive mechanisms. The methods used influence other types of noise always present to some degree, a measured reduction in actual subsonic noise only being found in the case of the radial vanes. From author's summary

3406. Hönl, H., On the sound field of a point-shaped sound source in uniform translatory motion, *NACA TM* **1362,** 44 pp., Apr. 1954. (Translation from *Ann. Phys. Leipzig* **43, 5,** 437–464, 1943.)

A rigorous analysis is presented of the excitation of sound by point sources moving in uniform translatory motion at subsonic or supersonic velocities through a two- or three-dimensional medium at rest. The construction of surfaces of constant phase is based upon Huyghens' principle in such a manner that the propagation in the medium at rest of the elementary waves emanating from the sound source is independent of the momentary state of motion of the sound source; hence, characteristic traits of the sound propagation may be understood even on the basis of simple geometric constructions.

From author's summary

3407. Cremer, L., Calculation of sound propagation in structures, *Acustica* **3,** 5, 317–335, 1953.

The different types of structure-borne sound waves are described and the wave lengths deduced. Especially the radiation into the air and the reciprocal transition are discussed. The impedances of simple types of structure are calculated and also the spectrum of impact sounds.

Finally, paper deals with the reduction of longitudinal and flexural wave amplitudes afforded by change of section, transition from rod to plate, corners, elastic layers, and impeding masses. From author's summary

3408. Ancell, J. E., A practical noise reduction treatment for diesel engines, *J. acoust. Soc. Amer.* **25, 6,** 1163–1166, Nov. 1953.

The treatment consisted of a set of sheet-metal covers, lined internally with acoustical absorbing material, which were mounted directly over the noisy areas of the engine by means of built-in vibration isolation. The speech interference level of the engine noise at six feet was reduced from 87 to 82 db. Straightforward experimental procedure; no new technique or theory is advanced. E. G. Fischer, USA

3409. **Meyer, E., Kurtze, G., Severin, H., and Tamm, K., A large new free anechoic and nonmagnetic room** (in German), *Akust. Beihefte* no. 3, 409–420, 1953.

The construction of a large free-space room is described, the inner dimensions of which are $5.5 \times 10 \times 14 m^3$, and which is anechoic for acoustic waves above 1000 mc/s (below 30 cm wave length); here the reflection factor of the walls is below 10% referred to amplitudes.

The walls are lined with wedges of 13×40 cm² in basic cross section and 90 cm in length. They consist of several layers of glass-fiber boards of the density 150 kg/m³. Three wedges form a unit (base 40×40 cm²) which can easily be suspended on the wall. An air cushion (12 cm thick) behind the wedges together with slots between the wedges acts as an acoustic resonator, which shifts the low cut-off frequency of the absorption to 70 c/s. The glass-wool wedges are made electrically absorbent by sucking in graphite powder (6.7% by weight). Due to careful preparation, the fabrication of the wedges and lining the room with the wedges took only a few weeks. The reflection factor for perpendicular sound incidence was permanently controlled during the fabrication by means of a standing wave tube. Reflection measurements for oblique incidence were made with a model wall. A large net made from thin steel cables allows one to walk easily through the whole room.

After the room was finished, its acoustic quality was tested by means of reverberation-time measurements (spark as a sound source, amplifier with a logarithmic characteristic, and cathode-ray oscillograph) and by measuring the deviations of the $1/r$-law of propagation (spherical sound source and unidirectional microphone). The latter procedure was also used for electromagnetic waves. The results show that the quality of the room is as good as one could hope for. From authors' summary

3410. **Kuhl, W., Oberst, H., and Skudrzyk, E., Impulse method for measurement of reflection from waterborne sound in tubes** (in German), *Akust. Beihefte* no. 3, 421–433, 1953.

The development of absorbers for water-borne sound covering the frequency range around 15 kcps required special measuring methods. The technique using the sound propagation in tubes proved to be appropriate for this purpose.

A pulse method is described which permits the determination of the amounts and the phase angles of the reflection factors of absorber samples, having the shape of circular disks, in a tube. This method was, in the first instance, applied to the case of resonant sorbers. The influence of the narrow annular slot between the sample and the wall of the tube is especially treated, also the necessary elimination of the systematic error which is caused by the slot. From authors' summary

Soil Mechanics, Seepage

(See also Rev. 3199)

3411. **Evans, I., The sinkage of tracked vehicles on soft ground,** *Brit. J. appl. Phys.* **4,** 11, 330–334, Nov. 1953.

After reviewing the theoretical works of Micklethwait and Sherratt, author presents a theory of deep sinkage based on inductive reasoning. His assumptions are: (1) The maximum bearing capacity $\bar{q}$ occurs when the penetration is twice the width of the track; (2) a high proportion of $\bar{q}$ is achieved for smaller penetrations than $2b$; (3) the curve of the track between bogie wheels is negligible at maximum bearing capacity. Based on these assumptions, he derives an expression for bearing capacity at maximum sinkage. For shallow sinkage, he assumes that the elastic theory holds, and develops expressions for the lowest bearing value at which sinkage can be regarded as zero. Having determined expressions for two theoretical points on the sinkage curve, the form of the curve is assumed to be similar to curves determined by field tests, and the theoretical equation for the entire curve is established. Comparison with field tests shows good agreement at deep sinkage and not as good at shallow sinkage. The deep sinkage end of the curve is considered most important.
F. J. Converse, USA

3412. Kellogg, F. H., Construction methods and machinery, New York, Prentice-Hall, Inc., 1954, xv + 415 pp. $10.

Author describes construction procedures and use of construction machinery in time-motion relationship. The book is intended for construction supervisors, estimators, and designers of heavy construction. The writing vacillates somewhat from the engineering level to the level of clearing foreman.

There is little information in the book concerning structures, and it is felt that its principal value is for earthwork and foundation preparation. E. J. Runyan, USA

3413. Bendel, L., Dynamic problems concerning strength of soils, *Wwys. Exp. Sta. Transl.* 53–7, 30 pp., Nov. 1953 (translated from *Travaux* **32,** 166, 445–452, Aug. 1948, by Geddings, W. W., Jr.)

New formulas permit making studies of settlement under repeated static and dynamic loads; for example, under airplanes, machine foundations, road vehicles, etc.
From author's summary

3414. **Shestopal, A. O., Problem of "arbitrary" subsidence of water-saturated sands** (in Russian), *Gidrotekn. Stroit.* **22,** 4, 1–5, Apr. 1953.

Author determined the critical void ratio of five typical sands by means of a box shear apparatus equipped with a perfected device for measuring the average vertical displacements. Using practical experiences with normally compacted sands, author concludes that the critical void ratio cannot be used as a criterion of the possibility of the "arbitrary" subsidence of the saturated sand dams.

Author fixes the degree of loosening under dynamic effects by the ratio of the pore-water pressure due to the lateral blow of a hammer and its highest possible static value. At a given density, this ratio approaches zero. Experiments show that dynamic influences can also cause loosening of rather dense sands.
L. Šuklje, Yugoslavia

3415. **Terzaghi, K., Origin and functions of soil mechanics,** *Trans. Amer. Soc. civ. Engrs.* Pap. no. 2619, *Centennial Trans.,* 666–696, 1953.

Paper gives an account of the influence of soil mechanics on some of the branches of earthwork and foundation engineering, such as the design of retaining walls, building foundations, and earth dams. It concludes with a review of the present trends in soil-mechanics research. These trends are chiefly determined by the practical difficulties involved in obtaining the basic data for theoretical solutions. From author's summary

3416. **Karafiáth, L., Some problems of earth pressure,** *Acta Techn. Hung. Budapest* **7,** 3–4, 313–339, 1953.

The first part of the paper demonstrates that the objection to Coulomb's classical earth-pressure theory, that conditions of equilibrium are not fulfilled in case of oblique earth pressure, is only the consequence of an unjustified assumption of linear distribution of stress along the slip plane and the back of the retaining wall. If stresses are correctly assumed, it is only in case

of horizontal earth pressure that the point of application of earth pressure is at one third of the height; if there is wall friction acting, i.e., in case of oblique earth pressure, the point of application is above the one third of height, as proved by experiments.

The second part of the paper deals with earth pressure acting externally, on the outer surface of circular structures. On basis of the Coulomb principle, with consideration of the value of pressure at rest ζ acting on the sides of the sliding wedge of earth, the angle of inclination of the generating line of the failure body, and the hydrostatic coefficient K_0 as a function of the height of the wall (m) and of the radius (r) are determined. In case of a given value of pressure at rest ζ, according to the calculations hydrostatic coefficient K_0 is a linear function of ratio m/r.

From author's summary

3417. Breitenöder, M., Infiltration phenomena on a dammed river (in German), *Wasserwirtschaft* **44,** 5, 113–119, Feb. 1954.

A fragmentary treatment is given of some two-dimensional cases of Darcy flow in homogeneous soil (seepage loss through levees, under a weir, and along its sides) with rough quantitative estimates. For more elaborate treatment, author refers to his book, "Plane ground-water flow with free surface" (in German), Berlin, 1942. H. J. Schoemaker, Holland

3418. Rorabaugh, M. I., Graphical and theoretical analysis of stepdown test of artesian well, *Proc. Amer. Soc. civ. Engrs.* **79,** Separ. no. 362, 23 pp., Dec. 1953.

Graphical method for determination of laminar and turbulent head losses in and close to wells and method for computing head-loss distribution outside a well for various pumping rates. Analysis shows variation of specific capacity with discharge and importance of well radius. J. C. Geyer, USA

3419. Petersen, J. S., Rohwer, C., and Albertson, M. L., Effect of well screens on flow into wells, *Proc. Amer. Soc. civ. Engrs.* **79,** Separ. no. 365, 24 pp., Dec. 1953.

Paper reports tests and develops theory of hydraulics of well screens which show that $11.31\, C_c A_p L/D$ should be greater than 6 to keep screen losses low. C_c is coefficient of contraction, A_p is percentage open area of screen, L screen length, and D the screen diameter. J. C. Geyer, USA

Geophysics, Meteorology, Oceanography

(See also Rev. 3144)

3420. Cressman, G. P., An approximate method of divergence measurement, *J. Meteor.* **11,** 2, 83–90, Apr. 1954.

Assuming no divergence at 600 mb, an equation for the divergence at 850 mb is used to aid in deducing the weather to be associated with prognostic charts of pressure and thickness. Usual simplifying assumptions are made. Many charts of test cases are given. Data density is too sparse for thorough check. Experience in use of method certainly helps and some useful quick results can be obtained with practice. Some refinements of Sutcliffe's work are discussed but are not of major consequence. Paper is most useful to those trying similar methods who wish to benefit from author's experience. R. S. Scorer, England

3421. Sicinski, H. S., Spencer, N. W., and Dow, W. G., Rocket measurements of upper atmosphere ambient temperature and pressure in the 30- to 75-kilometer region, *J. appl. Phys.* **25,** 2, 161–168, Feb. 1954.

Using rocket sondes and applying well-known supersonic aerodynamic theory, authors have obtained an indirect measure of pressures and temperatures in the upper atmosphere from suitably located pressure-sensing elements on a rocket nose cone. In addition to a pressure-ratio measurement by Alphatron ionization gages, other necessary data include rocket attitude measurements furnished by gyro reference and an adequate rocket velocity vector obtained from external tracking instrumentation.

An expression for Mach number is developed in terms of specific heat ratio and the ratio of cone tip to cone sidewall pressures for the yawing and non-yawing cone. From the Mach number and relative flight speed the ambient temperature is calculated. The ambient pressure is available from the same basic data.

Results are given for two flights at White Sands Proving Ground, N. Mex. Data agree fairly well with temperatures adopted by Upper Atmosphere Rocket Research Panel when consideration is given to the fact that Panel atmosphere represents yearly average, while it is known that fairly large seasonal variations exist. W. W. Berning, USA

3422. Starr, V. P., Note concerning the nature of the larger-scale eddies in the atmosphere, *Tellus* **5,** 4, 494–498, Nov. 1953.

The rate of generation of kinetic energy of mean zonal motions by the large-scale horizontal eddies in the atmosphere is computed from three independent sets of hemispheric wind data. The results are larger than certain analogous dissipation estimates would require. Meteorological implications of the material are discussed. From author's summary

3423. Okubo, A., A note on the growth and temperature variation of the "convection layer," *Oceanogr. Mag.* **5,** 1, 15–22, June 1953.

3424. Fraser, D., Meteorological design requirements for icing protection systems, *Nat. aero. Establ. Canad.* LR-49, 37 pp., Mar. 1953.

3425. Carlstead, E. M., A study of constant absolute vorticity trajectories on isentropic surfaces, *J. Meteor.* **10,** 5, 357–361, Oct. 1953.

Constant absolute vorticity (CAV) trajectories are shown to be more useful on isentropic surfaces than on constant pressure surfaces. The results of forecasts both on isentropic and 500-mb charts are treated statistically, and forecasts from CAV trajectories on isentropic charts are shown to be significantly better than similar forecasts from 500-mb charts.

H. Arakawa, Japan

3426. Woodcock, A. H., Salt nuclei in marine air as a function of altitude and wind force, *J. Meteor.* **10,** 5, 362–371, Oct. 1953.

Since very large condensation nuclei probably play an important role in the formation of rain by accretion, and since large sea-salt particles may make the largest contribution to these nuclei, author has investigated the variations in number and size of large airborne salt particles at cloud level in marine air in the trades, especially the Hawaiian Islands.

Samples have been accumulated by airplane for 37 days. They show that the number of particles of all sizes increases with the wind speed in a given volume; the number of large particles increases by factors as much as 10^5 from Beaufort 1 to 12. The total weight of salt in the air increases 10 to 100 times over the same range of wind speed. These great increases are thought to be due to an increase in the number of bubbles produced in white caps at the ocean surface, which project small drops of water into the

air. Horizontal plane traverses indicated large fluctuations in the salt content over short distances. Thus, adjacent growing cumuli may extend into a greatly differing environment near their tops.

The gradient of salt content from windward to leeward side of several of the Hawaiian Islands was such as to suggest that when a marked decrease of salt content occurs it may be explained by particles being rained out in showers in the central mountains.

H. Riehl, USA

3427. **Bolin, B., The adjustment of a non-balanced velocity field towards geostrophic equilibrium in a stratified fluid,** *Tellus* **5,** 3, 373–385, Aug. 1953.

The previous work by Rossby and Cahn on the adjustment of a nonbalanced velocity field toward geostrophic equilibrium has been generalized to incorporate the corresponding process in a stratified but incompressible fluid. It is shown that the character of the process depends essentially upon the width of the current, the velocity profile in the vertical, and the vertical density gradient. If the density gradient is small, the mean motion is adjusted quickly, as described by Cahn. If there are vertical variations of the unbalanced motion, there will be large oscillations whose speed is much less than the speed of waves generated during adjustment of mean motion.

Paper represents a significant extension of earlier work by Cahn, but reviewer believes that there is need for further extension to the compressible atmosphere in order that effects of temperature changes in upper atmosphere may be assessed.

R. G. Fleagle, USA

3428. **Atlas, D., and Plank, V. G., Drop-size history during a shower,** *J. Meteor.* **10,** 4, 291–295, Aug. 1953.

A sequence of five closely spaced raindrop samples taken during the passage of a shower displayed approximate monodispersity in each sample, and drops decreasing to drizzle size with time. Correlations of median volume diameter and of liquid-water content with rain intensity agree very well with previously established empirical relations, except for the very first drops. However, values of reflectivity ($Z = \Sigma Nd^6$) are approximately half those predicted by $Z = 200R^{1.6}$, due primarily to the narrow drop-size spectra. Such variations in spectrum width may be accounted for by varying the coefficient of the Z-R relation.

The smallest particles are shown to originate at the very edge of the shower, having evaporated during their fall. The largest particles originate toward the inner portion of the shower and probably grow to some extent by coalescence in the cloud before evaporating slightly underneath it. All the drops appear to have originated above the melting level.

From authors' summary

3429. **Gleeson, T. A., Effects of various factors on valley winds,** *J. Meteor.* **10,** 4, 262–268, Aug. 1953.

A relation is derived for the periodic valley wind as a function of time and elevation, in terms of the diurnal temperature variation, slope of the valley floor, eddy viscosity, the Coriolis force, and a pressure force representing the constraining effect of the valley walls. The theoretical wind is examined in several postulated situations. It is shown that more realistic representations of the valley wind are possible when effects of the Coriolis force are considered than when neglected. From author's summary

3430. **Ôkita, T., On the mechanism of dissipation of fog by a model wood (Experimental investigation in a forest),** *J. meteor. Soc. Japan* (2) **31,** 7, 1–11, July 1953.

3431. **Lindner, C. P., Intrusion of sea water in tidal sections of fresh water streams,** *Proc. Amer. Soc. civ. Engrs.* **79,** Separ. no. 358, 35 pp., Nov. 1953.

3432. **Satô, Y., Study on surface waves. IX. Nomogram for the group velocity of Love-waves,** *Bull. Earthq. Res. Inst. Tokyo Univ.* **31,** part 4, 255–260, Dec. 1953.

3433. **Ricker, N., Wavelet contraction, wavelet expansion, and the control of seismic resolution,** *Geophysics* **18,** 4, 769–792, Oct. 1953.

Superposition of simple wavelets suggests possible interpretations of seismograms. However, seismographs cause distortions, particularly when filtering is used to suppress ground roll. For distortionless seismographs, phase characteristics must be linear with intercept n_π, n integer or zero, and amplitude response must have the form $A_0 \exp(kf^2)$. Latter condition is new and insures similarity of input and output, contraction and expansion occurring for positive and negative k, respectively, with simultaneous peak frequency shift. In field tests, effect of wavelet contraction has been found superior when reflections are well defined. Wavelet expansion is suggested in presence of too many reflections in order to suppress resolution. J. R. M. Radok, Australia

3434. **White, J. E., Signals in a borehole due to plane waves in the solid,** *J. acoust. Soc. Amer.* **25,** 5, 906–915, Sept. 1953.

Approximate method is developed for calculating pressures generated in a water-filled borehole under influence of plane elastic waves in the earth. Assumption is made that behavior of water at any depth depends on displacements which would occur if the local applied stresses were homogeneous and the borehole were empty, plus the displacements produced by the pressure wave generated in the water by the first set of displacements. F. R. N. Nabarro, South Africa

Lubrication; Bearings; Wear

3435. **Stephan, H., Evaluation of bearing materials** (in German), *ZVDI* **96,** 11/12, 341–346, Apr. 1954.

To aid in calculating maximum load capacity of a journal bearing, concept of a figure of merit for bearing material is introduced. Equation derived for figure of merit defines it as a constant relating maximum load to bearing dimensions, running conditions, and elastic properties of bearing materials. Experimental curves are included to show how these factors affect maximum load at failure of bearing; curves calculated from proposed figure-of-merit equation show reasonable agreement with experimental results. Figures of merit for several bearing materials, and corresponding maximum loads for various running conditions, are given in a table. T. P. Goodman, USA

3436. **Kettleborough, C. F., The stepped thrust bearing—a solution by relaxation methods,** *J. appl. Mech.* **21,** 1, 19–24, Mar. 1954.

See AMR **7,** Rev. 1343.

3437. **Gut'yar, E. M., Calculations concerning a sliding bearing under a dynamic load** (in Russian), *Izv. Akad. Nauk SSSR Otd. tekh. Nauk* no. 5, 762–766, May 1953.

3438. **Kolano, F. J., Study of lubricant flow in bearings by streak photography,** *Prod. Engng.* **24,** 10, 162–163, Oct. 1953.

3439. Peterson, M. B., and Johnson, R. L., Friction and wear investigation of molybdenum disulfide. I—Effect of moisture, *NACA TN* 3055, 28 pp., Dec. 1953.

NACA investigation is extended to include influence of moisture on rubbing surfaces lubricated with molybdenum disulfide. Tests were conducted at sliding speed of 5.7 fpm between 1020 steel flat and a 3-lobe 4620 steel rider with loose powder; friction increases as humidity rises, but becomes smaller as 100% relative humidity is approached. Bonded films showed a similar trend. Damage continues to become more severe, however. Large differences in friction were noted between sliding parallel to finish marks and perpendicular. Corrosion was noted when moisture contacted the steel and molybdenum disulfide.

The desirable friction and damage properties of molybdenum disulfide under dry conditions recommend its use under those conditions where other dry lubricants are unsatisfactory.

J. B. Bidwell, USA

3440. Stephan, H., Temperature and attitude of journal bearings at high speed (in German), *VDI-Forschungsheft* (B) **19,** 439, 36 pp., 1953.

Author has made numerous tests on journal bearings at high speed (up to 25,000 rpm). He investigates chiefly the dependence of bearing temperature on different operating conditions (speed, load, radial clearance, bearing length, temperature, and pressure of inlet oil) and its influence on friction coefficient, power loss, and oil consumption.

The attitude is almost completely defined by the temperature distribution. It is assumed that the locus of the minimum film thickness is the same as that at which the temperature is a maximum. The value of eccentricity will then be computed by means of an empirical formula.

Equations are deduced from the theory of hydrodynamic lubrication in order to permit comparison with the tests.

The results are dealt with in a form which is suitable to serve as a foundation for the design of journal bearings, where friction heat is removed only by the oil flow. Thus it is possible to compute the mean bearing temperature, derating, and oil consumption. For the relative clearance, values are given which guarantee a safe run. They reach a value of about 5×10^{-3} at a bearing surface velocity of 100 m/s = 4000 in./sec. The stated clearances enable a calm run without shaft whirl (a self-excited vibration, which can occur at high speeds). H. Drescher, Germany

Marine Engineering Problems

(See also Rev. 3426)

3441. Johnson, A. J., and Meek, M., Stress investigations on a tanker during launching, *N. E. Cst. Instn. Engrs. Ship. Trans.* **70,** 4, 253–278, Feb. 1954.

Tanker is of single-screw type for service speed of 13¾ knots with two corrugated longitudinal bulkheads, longitudinal frames at deck and bottom, transverse frames at sides, and length BP 445 ft. Strains were measured at deck and bottom by autographic gages with measuring lengths of 100 inches. Static strains and deflections were also measured with ship afloat before and after imposing known bending moments. Deflections were small and agreement between theoretical and observed values was poor; the greater part of the discrepancies are considered as due to thermal effects.

During launching, maximum stresses occur when stern starts to lift. Maximum measured change of stress was 1.9 tons/sq in. in deck and 1.62 tons/sq in. in bottom, with corresponding theoretical values 1.5 and 1.25 tons/sq in., respectively. Calculation assumed trapezoidal distribution of load on ways without considering deflection.

When vessel commences to move, there seems to be a tendency for hull girder to straighten. Deflection or spring coefficient of ways seems to contain a time factor. Apparent neutral axis with deck in compression seems to lie 7½ inches below theoretical neutral axis of hull girder, assuming simple beam theory. Molded depth is 34 ft. G. Vedeler, Norway

3442. Hoard, R. J., and Acurso, L. A., Designing gears for gas-turbine marine applications, Soc. nav. Arch. mar. Engrs. Prepr. Spring Meeting, Seattle, Wash., May 17–18, 1954. Pap. no. 3, 15 pp.

3443. Alfers, J. B., and Graner, W. R., Reinforced plastics—a structural material for marine applications, Soc. nav. Arch. mar. Engrs. Prepr. Spring Meeting, Seattle, Wash., May 17–18, 1954. Pap. no. 1, 18 pp.

3444. Weinblum, G. P., On the directional stability of ships in calm water and in a regular seaway, Proc. First U. S. nat. Congr. appl. Mech., June 1951; J. W. Edwards, Ann Arbor, Mich., 43–47, 1952.

Author discusses added masses and derivatives of vertical force and yawing moment for a body moving on the surface. Use of steady-state flow conditions in stability work can be fundamentally wrong as far as influence of the free surface is concerned. The derivatives and added masses can be correctly defined only in terms of actual flow pattern. However, in many cases free surface effects are small.

Author shows, in principle, how inertia coefficients can be estimated in the case of a body advancing with constant speed when the disturbed motion is impulsive or uniformly accelerated. As no solutions have been obtained for added masses in case of an initial motion starting with zero acceleration, no final recommendation can be given as to what values of inertia coefficients should be inserted into equations of motion. A satisfactory solution is expected in the near future.

Splitting up the wave part of transverse force into two parts, one caused by the motion of the body in calm water and the other accounting for additional effects due to corrugation of the free surface by ship waves, author discusses influence of free water effects on the derivatives of these parts. He assumes similar conditions hold for wave part of yawing moment. No estimates can be made as yet on rotary derivatives.

Using approximate expressions for transverse force and yawing moment due to a regular seaway, author discusses the resulting equations of motion. Making some simplifying assumptions he then gets a single Hill equation, parameter of which depends on many variables. Treating a typical case and using values from earlier investigations, he gets small values for the parameters and the Hill equation reduces to a Mathieu equation.

E. Steneroth, Sweden

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